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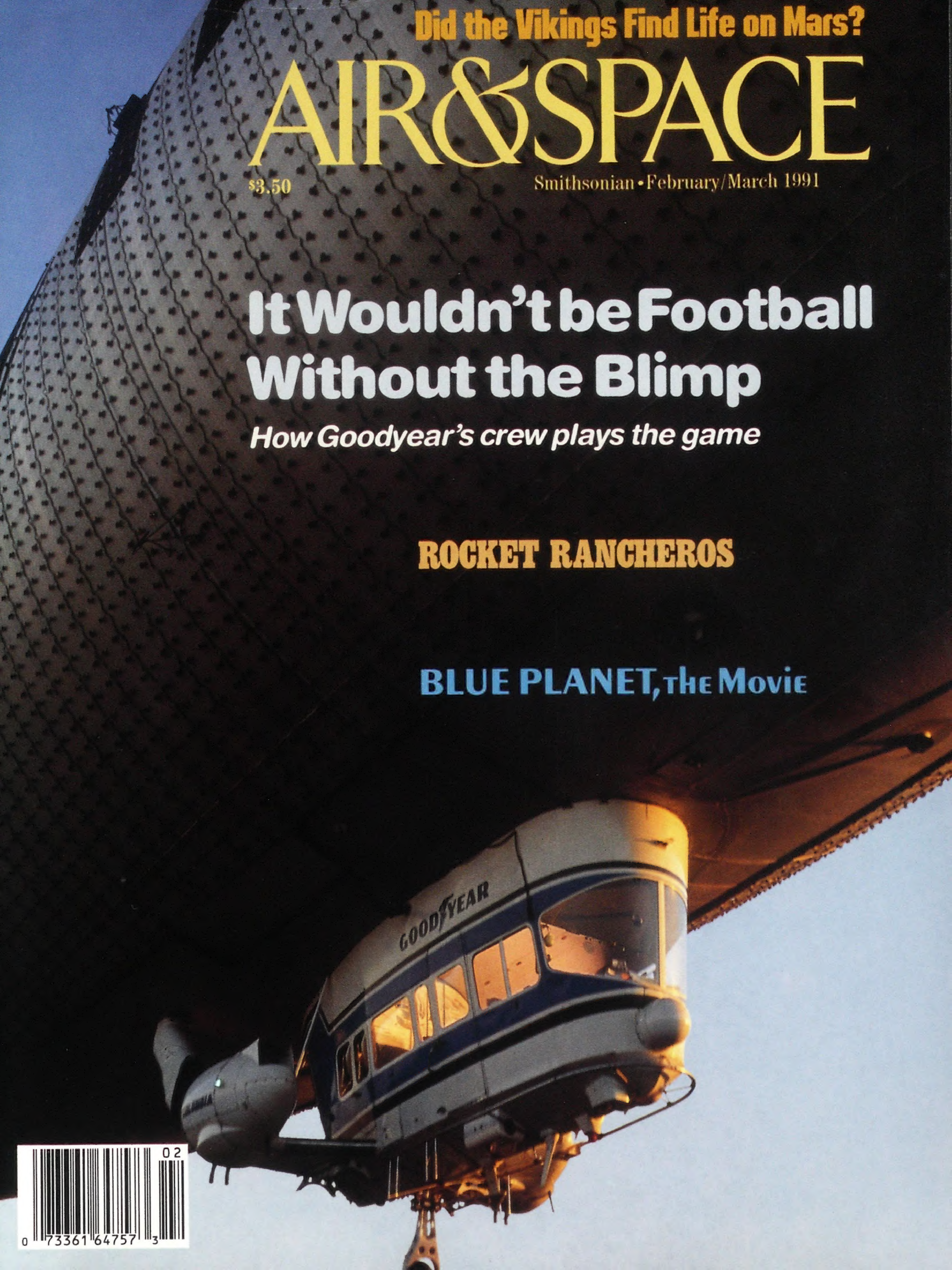

February/March 1991
Volume 5, Number 6

AIR&SPACE
Smithsonian

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Cover: Chad Slattery photographed one of Goodyear's famed inflatables the way its ground crew sees it.

AIR & SPACE/Smithsonian (ISSN 0886-2257) is published bimonthly by the Smithsonian Institution, 900 Jefferson Drive, Washington, DC 20560. Subscription price: $18 a year in U.S. possessions, $24 elsewhere. Eighty-five percent of dues is designated for magazine subscription. Single-copy price: $3.50. Second-class postage paid at Washington, DC, and additional entry points. Editorial offices: 370 L'Enfant Promenade SW, 10th Floor, Washington, DC 20024. Advertising and circulation offices: 420 Lexington Ave., New York, NY 10170. Members: Address all subscription correspondence and change-of-address information to P.O. Box 53261, Boulder, CO 80322-3261. Postmaster: Send address changes to *AIR & SPACE/Smithsonian*, P.O. Box 53261, Boulder, CO 80301-3261.

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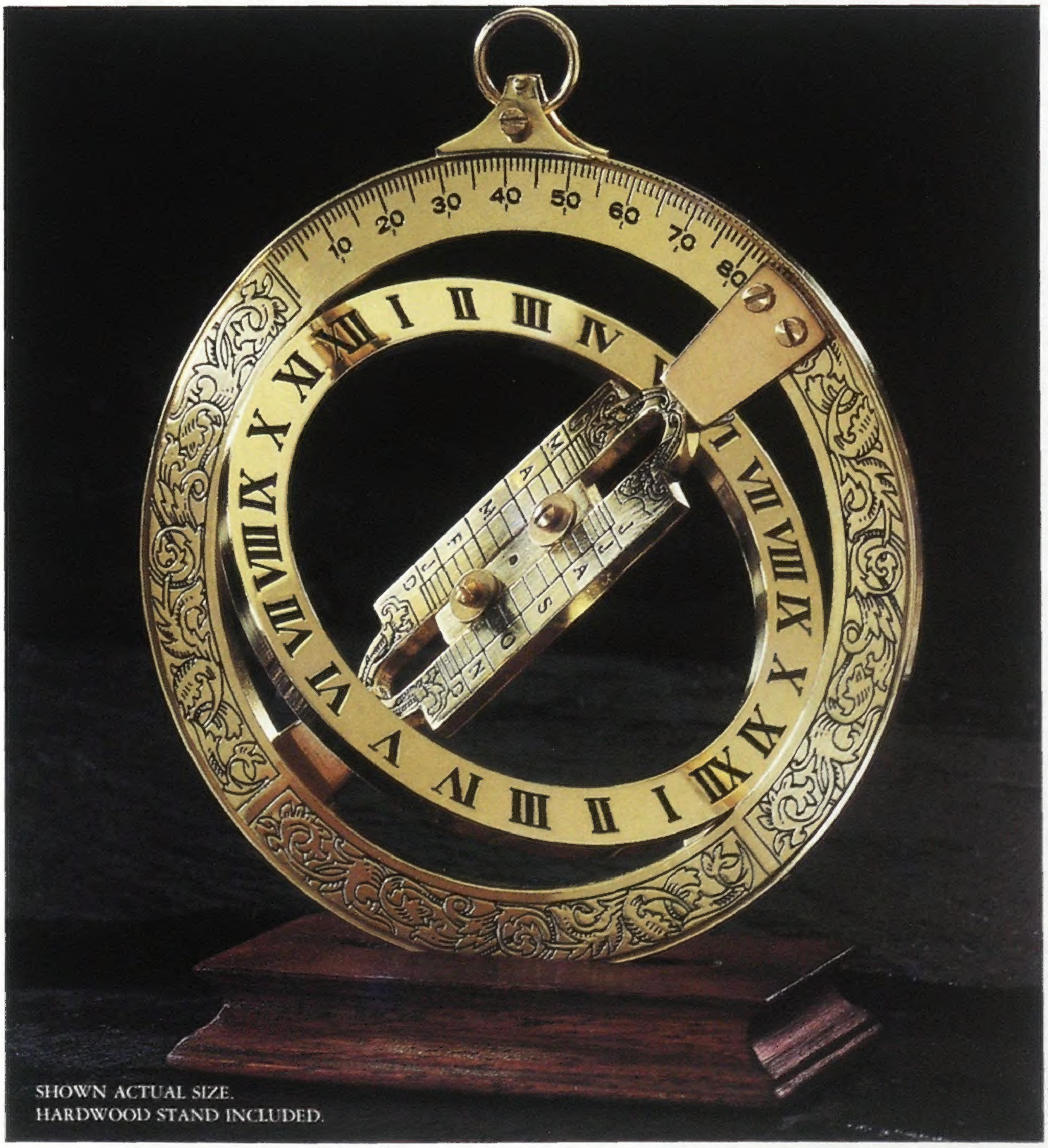

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Viewport

Space Hurdle

Before the full promise of space can be realized a major hurdle must be overcome. It is the enormous cost of launching men and instruments into Earth orbit.

This cost varies from launch to launch, but typically it is around $10 million per pound. And that's just the launch cost, and does not include the substantial cost of building the spacecraft or instruments on board.

While no simple cost reduction measures are in sight, it is worth examining the issue to see where the main expenses arise and savings could be realized.

When we see a giant rocket rising into the sky, we get the impression that an enormous amount of energy is required to put a payload in orbit. But that's deceiving. The energy needed to raise a body to a height of a few hundred miles and give it a velocity sufficient to keep it in orbit is astonishingly small. The orbital energy per pound of payload turns out to be roughly equivalent to the heat generated in burning one pound of ordinary fuel costing well under one dollar.

Payload orbital velocities, typically around 18,000 mph, are only a few times higher than muzzle velocities of bullets or shells fired from cannon. And the cost per pound of firing those projectiles again is very low.

Moreover, other types of cannon, based on the electromagnetic principles used in accelerating nuclear particles in an atom smasher, could quite easily accelerate a payload to orbital velocity at low cost. Admittedly, such an accelerator would need to comprise a track a hundred miles long if the acceleration is to be sufficiently gradual to avoid the high G-forces that would crush most payloads, but that is not the major problem.

Why, then, is it so expensive to launch orbital payloads?

The principal roadblock is the atmosphere. If we lived on the moon, which has no air, launches would be far simpler. A few years ago Princeton physicist Gerard K. O'Neill proposed that if material for space construction projects were mined on the moon and transported into space from there, the cost of launch would be much lower. He proposed an electromagnetic accelerator that would send projectiles hurtling along a rail that could be laid out on the moon's surface. When these projectiles reached escape velocity, they would leave the end of the rail and continue to travel out into space, overcoming the moon's gravitational attraction. Once in space, the capsule would be retrieved and its payload put to use.

This system won't work on the surface of Earth because the air drag would become impossibly severe, heating the leading edge of the projectile and vaporizing it. To some extent, that problem can be overcome by taking a projectile to high altitudes and launching it where the air is less dense and the drag is lower. A small step along that line has already been taken in developing the Pegasus vehicle, carried to high altitude by an airplane before launch. A wing then permits it to obtain added lift, raising it to even higher altitudes.

The problem with conventional chemical rockets is that nozzle exhaust velocities, just like cannon muzzle velocities, are low compared with orbital velocities. To efficiently compensate for these low exhaust velocities, we successively mount one rocket on top of another, in stages, each launching a subsequent stage to progressively higher velocity. In this process we accelerate a sequence of fuel reservoirs to ever-higher speeds, only to discard them after their fuel is spent. So wasteful is this process that the final payload weight of a typical orbital mission often is only one-hundredth of the total pre-launch weight—though ratios as high as 1:20 have been attained.

How can this inefficiency be avoided and costs cut?

The answers aren't at all clear. The only certainty is that we will need highly imaginative approaches in the future to truly lower the cost of launch and tap the full potential of space. A great deal will ride on that.

—Martin Harwit is the director of the National Air and Space Museum.

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Letters

The Mourning Continues

It is sad that a grudge grounded the highest and fastest aircraft we had, the SR-71 ("The Blackbird's Wake," October/November 1990). As a U.S. Army Reserve MP currently serving in Saudi Arabia for Operation Desert Shield, I was pleased to read that there is a chance the Blackbirds will return to service. I sincerely hope and pray they will. It would give us a greater sense of security knowing we were up above the rest, watching. The Blackbird's intelligence would allow for the proper planning and coordination of actions and reactions.

PFC Kevin E. Barnard
Dhahran, Saudi Arabia

While stationed at Beale Air Force Base in California, my husband and I had the honor of being associated with that magical aircraft, the Blackbird. Your sidebar "Cold Storage" touched a deep chord in both of us. With great emotion we too watched the "Sled" land at Offutt Air Force Base in Nebraska after its last flight. The maintenance man who reached up and kissed the nacelle acted for all of us. It has been said that the SR-71 was the most advanced aircraft ever built, but it was more—much more. It represented all that was good about the American people who built, flew, and loved her.

Lora L. Swanson
Papillion, Nebraska

The SR-71 has successfully served our nation in gathering intelligence since the mid-1960s. Its mystique reflects the aesthetic and technical genius of that era. It is, however, aging. Currently deployed technology offers more cost-effective, flexible, and risk-reducing options. While

flying this old bird may have had a romantic glamour for its select group of 120 pilots, the public should not be saddled with the unnecessary contribution it makes to the budget deficit. Armed with the facts, most would agree with General Welch: the SR-71 will make a fine museum piece.

Blake C. Lawless
San Diego, California

Trivial Pursuit

After reading "Drag of the Intruder" (Soundings, October/November 1990), I thought how nice it is that the Navy has so much money for such trivial pursuits as drag racing with multimillion-dollar aircraft. As a technical sergeant in the Air Force, I am well aware of how much fuel a jet such as the A-6 burns in a very short time. If the A-6's engines ran for just one hour, I would guess that the taxpayers spent around $6,000 on fuel alone, not to mention wear and tear on the aircraft. I'm sure the Navy will try to justify the expense as "recruiting." Meanwhile we in the Air Force are rather short on cash and have been told of leaner times ahead. With fraud, waste, and abuse like this it's no wonder I can't get a pay raise equal to the inflation rate.

Steven R. Reinhardt
Kadena Air Base
Okinawa, Japan

Science vs. Exploration

In "Space Station and Colonization?" (Viewport, December 1990/January 1991) Martin Harwit has finally given space enthusiasts the lecture we've needed for some time. Before World War II, science was a good reason to send people into space. Pioneers like Tsiolkovski, Goddard, and Oberth had to assume that people would explore space because there was no alternative. But during the war, engineers developed electronic proxies for human eyes, ears, and pilots. Scientists, interested more in data than in exploration, were quick to adapt these inventions to peacetime research. Circuits were and are safer, cheaper, lighter, and more durable than people. In the future, optical components and artificial intelligence will enable computers to approach human levels of judgment and analysis. The only science that requires people in space is human biology, and even then only if we plan to colonize space. This is a lesson we space enthusiasts have been slow to learn: if science is the mission, people just aren't necessary in space.

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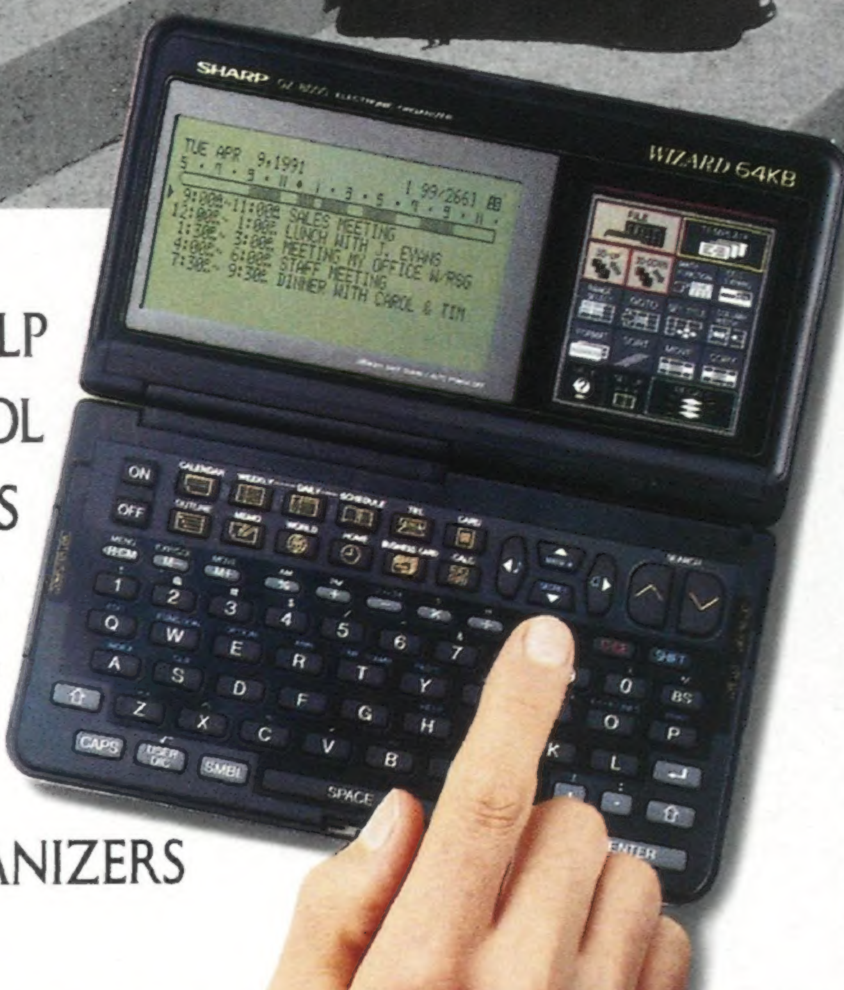

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It might be more honest to admit that we support the shuttle, space station Freedom, and other manned programs not for the science, not for the spinoffs, but for the excitement and romance. Through such adventures, we learn and grow as individuals and as a species. Is it right to spend public money on such intangibles? It is, and we do. Although we squabble over content and amounts, we all agree that government should support the arts simply because art satisfies emotional needs. Why, then, should government not support exploration and adventure? Science, economics, and politics have always been hitchhikers when we explore the unknown, but we should not try to justify exploration in those terms.

Bill Doorley
Pittsburgh, Pennsylvania

Martin Harwit extols the unmanned Soviet lunar missions that returned soil to Earth, saying "the first ounce counts for more than the next hundred pounds." Exactly, but that first ounce and indeed the first 123 pounds of lunar rock and soil were returned to Earth by the gallant crews of Apollo 11 and 12 in 1969. Not until September 1970 did the Soviet robot Luna 16 succeed in collecting and returning about three ounces of moon soil. Robots are great when they work, but there were repeated crashes of robotic lunar vehicles, including several Soviet craft that were sent to gather moon soil. In contrast, no manned craft that attempted a lunar landing failed to accomplish it or to return safely to Earth with its precious cargo.

Stephen P. Maran
Editor, The Reference Encyclopedia of Astronomy and Astrophysics
Chevy Chase, Maryland

Martin Harwit replies: A closer reading of my article will show that I never said that the Soviet Union returned lunar soil to Earth earlier than the United States. That question never was at issue. I'm grateful to Stephen Maran for pointing this out, in case any others might have misunderstood me.

Extraterrestrial Activities

Many thanks to Alex Heard for his exposé on *Out There: The Government's Secret Quest for Extraterrestrials* by Howard Blum (Flights & Fancy, December 1990/January 1991). The journalism credits accorded to Blum indicate that he should have produced a knowledgeable report, but obviously he failed to check his source materials thoroughly.

At any rate, there are private groups who started investigating extraterrestrial activity years before Project Blue Book and continue to do so today. These dedicated people have given the public an excellent, in-depth view of the UFO activity occurring on Earth. Any national government, particularly our own, would be very remiss in not having an ongoing, open-minded investigation of extraterrestrial activity. The objective: to organize a framework toward mutual understanding between Earth people and visitors from the cosmos.

Hugh C. Moore
Chalmette, Louisiana

Alex Heard approaches the subject by making Howard Blum look ridiculous and totally incompetent. Heard has the notion that by discrediting Blum personally, you can magically eliminate the extraterrestrial phenomenon. The question is not whether Blum is competent but whether we should start analyzing a scientific concept through character assassination. As a taxpayer, I hope and expect that our government is seriously interested in extraterrestrial intelligence. Curiosity and open-mindedness are the basis of discovery and progress for humankind.

Benjamin Gisin
Idaho Falls, Idaho

Renaissance Man

Your profile "Sherman Fairchild Looks at the World" (October/November 1990) was more like a Chekhov short story than an article for the aviation-hearted, but it was that as well. What a delight to be taken backstage and discover Sherman Fairchild—crazy inventor, slightly wistful bachelor, ecstatically contented workaholic—and realize that all those interesting Fairchild aircraft were associated with such a one. The irony of his death was wondrously operatic and I fancy he went with good cheer.

Keith Evans
San Diego, California

If Only We Had Known

Wayne Biddle's article "Two Faces of Catastrophe" (August/September 1990) raised some questions in my mind. I was an environmental test engineer at the Autonetics Division of North American Aviation until approximately two months before the Apollo launch pad fire. My work involved preparing an altitude chamber to test electronic equipment in an oxygen environment simulating the Apollo interior. Preparation consisted of removing the vacuum pump lubricating oil, disassembling the pump, degreasing all parts, reassembling, and finally servicing with an oxygen-compatible oil. The test chamber was set up in a "safe" area away from the main buildings. The test procedure began with installing the test article, pumping down the chamber, back-filling with oxygen to three pounds per square inch, and then cycling between three and five pounds PSI (the Apollo environment in space) with a slow "leakage" of oxygen into the chamber. The chamber had ports through which wires could be attached to the test article so that it could be operated. I was never asked to provide for an internal pressure of 16.7 pounds PSI, which is the pressure Biddle reports was used at Cape Kennedy.

The altitude (vacuum) chamber was not initially designed for an internal pressure, so additional modification would have been necessary.

To my knowledge, the chamber was never used. If it had, perhaps *we* would have experienced the explosion instead of the astronauts at Cape Kennedy. One hundred percent oxygen in contact with a combustible material at five pounds PSI is probably somewhat less dangerous than contact at a pressure of 16.7 pounds PSI, but at least we might have learned something.

Jack J. Orr
Lakewood, California

New and Improved History

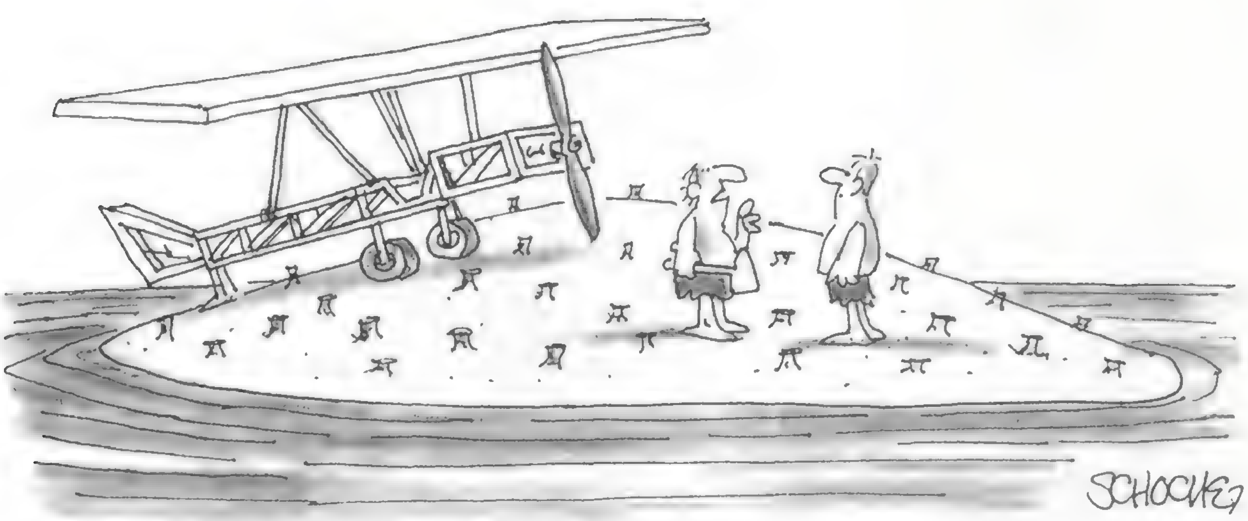
In response to Ben Nicks' letter stating that a museum's role is to "present history as it was, not as its curators would like it to be" (December 1990/January 1991), I'd like to explain two axioms of museums. First, history is revisionist. Those who win wars get to write it, and those who win subsequent wars get to rewrite it. A museum slants history to reflect and reinforce our own theories and attitudes as the winners of the conflict. Second, if Nicks really wants a collection of history as it is, he should visit a garbage dump. Museums are and always will be selective, and therefore they must edit and editorialize history.

Richard Ward
Lynbrook, New York

I'm in complete agreement with Ben Nicks. The museum moralizers are the same ones who want to disarm honest law-abiding citizens, do away with our Second Amendment rights, and play footsies with the communists.

Master Sergeant Joseph F. Connors
U.S. Air Force (Ret.)
Verona, Pennsylvania

While I thoroughly agree with the main point that Ben Nicks made in his letter, I take strong exception to a gratuitous statement concerning strategic bombing in Europe during World War II. Nicks is correct that moralizing should be kept out of museums, but he is far off base when he states that "strategic bombing failed when B-17s and B-24s could not knock Germany out of the war." Strategic bombing did not knock Germany out of the war, but it is incorrect to say that it failed altogether. I would refer Nicks to the U.S. Strategic Bombing Survey and the postwar testimony of Nazi military and industrial leaders, who have eloquently attested to the effect of



"All we need now is a large rubberband."

Allied bombing on production and communications. Perhaps General Georg Thomas of the German office of production summed it up best when he said: "Bombing alone could not have beaten Germany, but without bombing the war would have lasted for years longer."

Wayne G. LaPoe
2nd Bomb Group, Italy (B-17)
3rd Bomb Group, Korea (B-26)
Seattle, Washington

Corrections

Eugene Covert of the Massachusetts Institute of Technology points out that our comparison of a shock wave to a spoiler in "Mach 1: Assaulting the Barrier" (December 1990/January 1991) was not quite right. Although both relieve an airfoil of lift, a spoiler does it by deflecting air directionally, while a shock wave does it by increasing the pressure on the wing downstream of the shock wave. The word choice was the editor's, not the author's.

Air & Space America (Update, page 15, October/November 1990), a Kentucky firm established to manufacture the Air & Space Model 18A autogyro, is unrelated to Air & Space Manufacturing Inc., which declared bankruptcy. Former Pan Am pilot Don Farrington, who heads the new firm, was a dealer for Air & Space Manufacturing but was not involved in its management.

Sacramento Peak Observatory is in New Mexico, not Arizona ("Evidence of Cataclysm," December 1990/January 1991).

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When Chuck DeCaro came up with the idea for an airborne TV news service, he took care of two chores right away: selecting a name for his company—Aerobureau—and printing a brochure. Open the brochure to the first page and you'll find a depiction of a Lockheed Electra four-engine turboprop scanning "75+ miles" of newsworthy terrain with a side-looking airborne radar, or SLAR, as well as a remotely piloted vehicle (or RPV; Aerobureau has more acronyms than NASA) that flies over the really hot stuff with a TV camera. A dotted line represents electronic links from the RPV to the Electra and from the Electra "to satellite."

If this were a David Letterman production the camera would be called the Dronecam. But nothing about this is funny to DeCaro, who is mightily serious about Aerobureau. He has managed to corral a 1961 Lockheed L-188C Electra and a barnload of the electronics—including the SLAR—he needs to put his idea into operation. Now, with the support of AAI (formerly Aircraft Armaments but now just initials), he's rounded up another essential piece: the RPV. All DeCaro lacks is a contract with some purveyor—*any* purveyor—of TV news (Hello, CNN? . . .).

Last November, DeCaro and AAI hosted a demonstration of the RPV's role in the enterprise. Harford County Airport, a small country strip north of Baltimore, Maryland, was outfitted for the day with striped tents in which propane heaters roared to warm a

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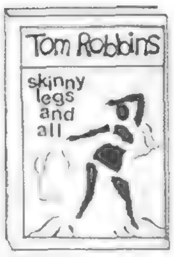

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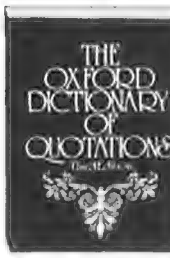

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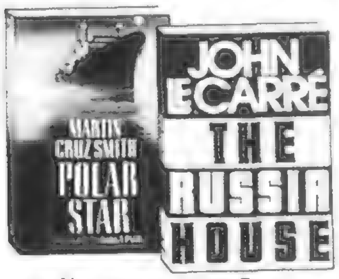

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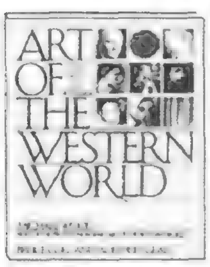

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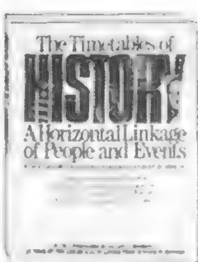

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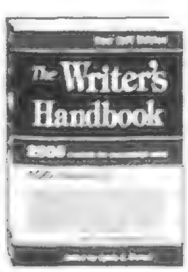

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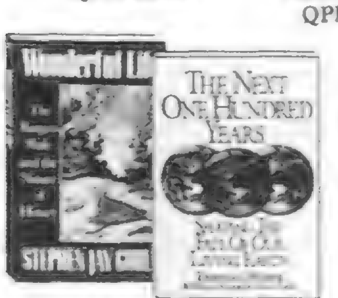

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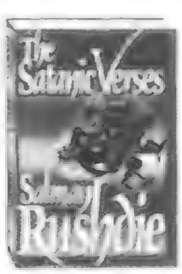

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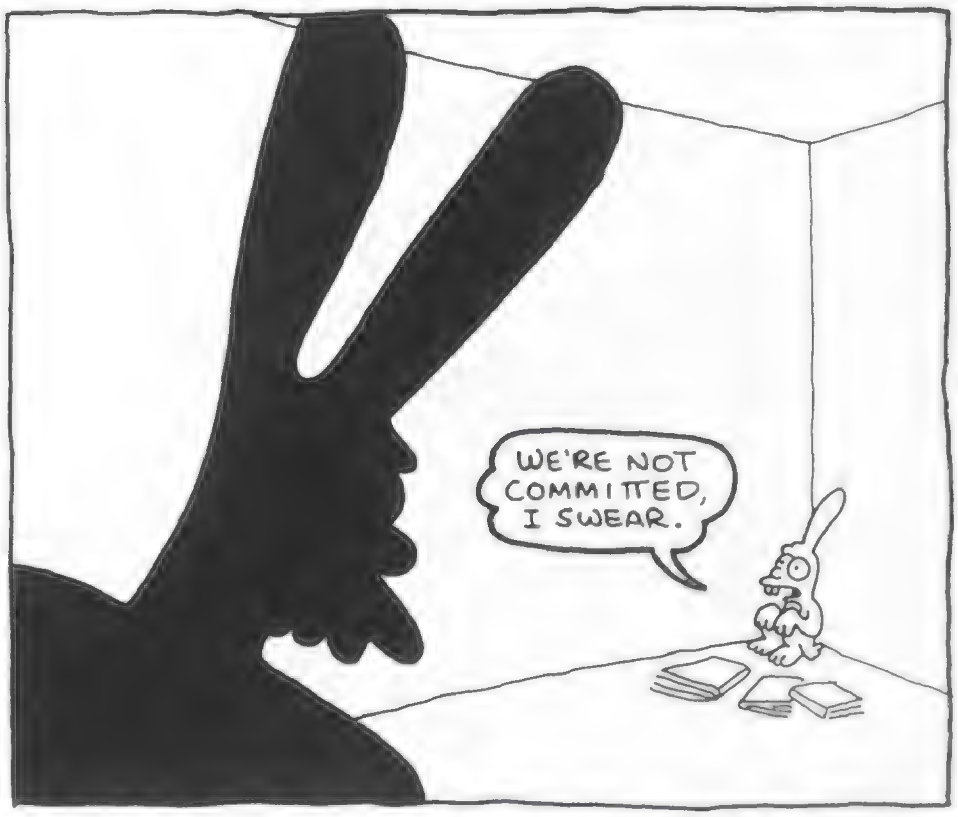

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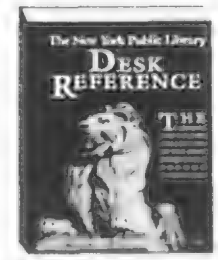

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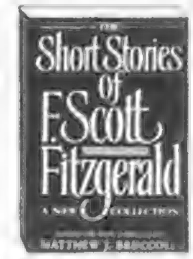

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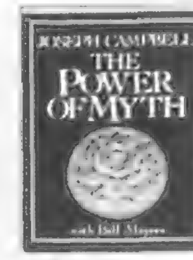

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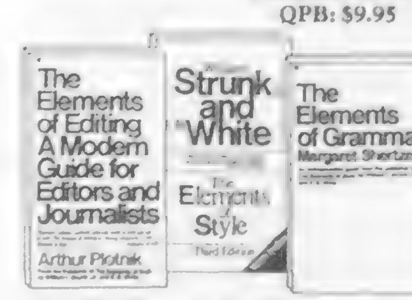

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chilled press corps. A portable generator chugged quietly among the trucks and cars parked on the grass. DeCaro, bustling about in a leather flying jacket bedecked with patches ("S.T.A.R.S." said one; that's Strategic Television Airmobile Reports-via-Satellite), juggled various electronic gadgets from cellular phones to beepers as he greeted newspeople he recognized.

With the wind strong and gusty, the day would prove a good test of any RPV. Harford County lacked an airport weather service, but a Cessna Skyhawk operating from the lone paved runway jousted with what looked like 20 gusting to 35—rough as a cob. After a briefing that explained how Aerobureau would have reported the Afghanistan earthquake, the Falklands war, the invasion of Kuwait, the Mount Saint Helens eruption, and various hurricanes and floods if only DeCaro had been given the chance, the AAI technicians, in matching red outfits, readied their mount for the day's mission. Its name, "Cyclone," was lettered on its flanks, a 19-horsepower engine driving a pusher propeller hung between its tail booms, and a tiny video camera was nestled in a small glassed-in compartment in its nose.

The engine snarled to life and settled into a rough chainsaw idle. A technician sent the signal for full throttle from an unseen switch and Cyclone began to roll. With very little fuss in all that wind, it took off. As it climbed to about 2,000 feet, several journalists went back inside the tent to watch the picture sent down from the RPV's $600 camera. Surprisingly steady—Cyclone has an autopilot that stabilizes it—the pictures were also astonishingly clear. You could not have recognized, say, Saddam Hussein in the crowd below, but you could have picked out his car if you knew its make and color.

AAI served sandwiches while some of the reporters took turns flying Cyclone from a remote control panel mounted on a pedestal near the runway. DeCaro, evincing pleasure at the success of the demonstration mixed with the frustration of trying for more than a year to get Aerobureau literally off the ground, worked the crowd. "Hey, good to see ya . . . Thanks for coming . . . All we need is our first shot . . . They'll all line up if we can just get one."

So far, the sticking point seems to be DeCaro's insistence that only his handpicked Aerobureau crews do the broadcasting. The networks want their own teams handling that. "I can't do this with untrained people on the airplane," DeCaro insists, a statement that conjures up Murphy Brown and the crew at "FYI" wreaking havoc at 11,000 feet.

—George C. Larson

AL KIRSCHENBAUM

"Mission Control, Columbia *here: Roger on Avenue F if you insist but we'll* never *find a parking place."*

Pioneer 11's Bad Attitude

Cold and lonely, the 500-pound spacecraft called Pioneer 11 sails ever outward from the sun, covering 200 million miles a year. Launched on April 6, 1973, when Richard Nixon was still president and astronauts were still riding around in Apollo capsules, Pioneer 11's itinerary was Jupiter, Saturn, and on into interstellar space.

Aside from discovering Saturn's "F" ring in 1979, the satellite has spent most of the last 18 years dutifully relaying news from the fringes of interplanetary space—a smattering of magnetic data here, a soundbite of the solar wind there. The routine has been sheer drudgery compared with the razzle-dazzle standards of space shuttles and the Hubble telescope.

But as if to remind NASA controllers not to take it for granted, Pioneer 11 called in sick last October. Its feeble eight-watt signal wavered, then ceased altogether. At NASA's Ames Research Center in California, Pioneer project manager Richard Fimmel declared a state of emergency and pondered his next move. Making a house call was impractical—the spacecraft was then some three billion miles from Earth, and radio commands would take four and a half hours to arrive.

The rescue effort Fimmel decided on hinged on the fact that Pioneer 11 normally transmits at whatever carrier frequency it hears from Earth. Engineers speculated that if the satellite's receiver had malfunctioned, the probe would be tone-deaf and thus unable to respond. On October 22, NASA sent the craft some strong medicine: a 350,000-watt command to switch to its backup receiver.

It worked, at least well enough to restore contact, and data began to trickle in again. But Pioneer 11 remains very hard of hearing. NASA continues to use its "Big Three" radio transmitters—the 230-foot dishes in California, Australia, and Spain—to shout at the errant probe, sacrificing communication sessions with other interplanetary craft, like Galileo and Magellan. Worse, Pioneer 11 is not holding its desired attitude and may soon lose track of Earth's location. Should that occur the craft would be lost for good. "If we can solve the attitude problem," says Fimmel, "we've got a good, solid mission for the next few years."

—J. Kelly Beatty

Update

Drone Launches Drone

The Navy has successfully launched a supersonic target from an unmanned aircraft ("Ensign Nolo, USN," August/September 1990). Last June a QF-4 drone, built by Beechcraft, took off from California's San Nicolas Island, accelerated to Mach 1.5, and launched the AQM-37C aerial target at 50,000 feet.

TOM FOOLERY (2)

Update

Comet Penetrator Axed

A penetrator being developed at the University of Arizona to impale Comet Kopff in 2001 and analyze its composition has been cancelled by NASA in a cost-cutting move ("To Spear a Comet," August/September 1990). The Comet Rendezvous Asteroid Flyby project will instead analyze debris ejected by the comet.

Carrot and Shtick

It is 1944. A P-38 with an orange fuselage sits on a beach at Funafuti in the South Pacific. A crew member is kneeling on a wing fueling it. The pilot must be resting in the tent behind the airplane. The laundry hanging on a line will surely get sandblasted when the engines start up. Behind a palm tree, a man-size rabbit eyes the carrots being loaded into the rocket launchers under each wing. Hey, wait a minute! Hold everything! What's that rabbit doing out of uniform?

"Fueling at Funafuti" is one of 17 whimsical moments that make up the Carrot Air Farce, a series of miniature tableaux by Tom Foolery. The San Francisco artist's work employs aircraft models with fuselages shaped into carrots with Bondo auto body filler and pilots with suspiciously long ears.

The Carrot Air Farce took root in 1977 when Foolery depicted a bunch of parachuting carrots in a work entitled "Carrot Troopers"—"just a nonsensical idea," he says. Months later he executed Carrot Troopers in 3-D when the San Francisco Museum of Modern Art invited him to enter an artist's soapbox derby. His entry was a 10-foot-long carrot with a green parachute that deployed halfway down the hill.

The transition to carrot airplanes was a natural. His first diorama, which featured another P-38, went on exhibit in 1978 at a Santa Clara, California museum and sold on opening night. "I didn't have it for very long," says Foolery. "I guess I missed it after a while."

Eventually Foolery began work on a full-scale orange air force. "It gave me an excuse to get back into model building," he says, "and still be working as an artist."

The scenes, each about 18 inches square, represent military aviation from World War I through present day. In them Foolery tempers historical accuracy with artistic license. A World War I SPAD, for example, wears a shark's-teeth grin, even though this motif did not appear on fighters until World War II. And, says Foolery, "the pilot being a rabbit was like taking the officer status one step further."

The Carrot Air Farce has been well received at airports, museums, and galleries across the country. There was, however, one tense moment at the Chevron Corporation gallery in San Francisco when a Chevron executive—and World War II Corsair pilot—previewed the exhibit. He came to a screeching halt at "Corsairrot," an orange Corsair being preflighted on a coral embankment while its pilot sips from a bottle of carrot juice. The ex-fighter pilot scrutinized the scene while Foolery waited for the ax to fall. Then he turned to the artist and asked, "How do you keep the carrot from rotting?"

—*Elaine de Man*

A Manhattan Project

Last November an A-12 Blackbird en route to a retirement home set yet another speed record: Galveston, Texas, to New York City at an average of 9.8 mph.

The A-12 reconnaissance craft, predecessor to the SR-71, traveled to the *Intrepid* Sea-Air-Space Museum on a barge. The month-long journey across the Gulf of Mexico and up the east coast had some uncomfortable moments between Galveston and Jacksonville, Florida. "We had really good attach points welded on the barge," says Jerry Roberts, the museum's technologies curator, "but when we hit the Gulf Stream the waves came right over it. It did move a bit."

A-12 serial no. 60-6925, which first flew in 1962, was the first production version of the CIA's "test article," as the airplane was called during its development, and to this day its history is cloak-and-dagger stuff. "There's no flight log records or in-flight pictures available for it at all," Roberts says, though it's said that the A-12's lighter weight enabled it to fly a bit faster and higher than the SR-71.

Of the fifteen A-12s built, eight had been stored in Lockheed's Palmdale, California plant for the last 23 years, and recently the Air Force offered six to museums, provided they could figure out how to spirit them out of Palmdale. Though Roberts calls the retiring of the Blackbirds "an absolute political sin," he's pleased as punch that the museum snagged such a rarity. "We

JOHN SOTOMAYOR/NYT PICTURES

managed to lobby the right people," he says, grinning like a canary-fed cat.

On this cold December morning, Number 925 is sitting on the barge some 75 feet below the flight deck of the 48-year-old Essex-class *Intrepid* aircraft carrier, which since 1982 has been permanently docked at Manhattan's Pier 86 on the Hudson River. The Blackbird is due to be lifted from the barge at 11 a.m. and set down among vintage folded-wing Navy fighters by an enormous crane on a turntable. Never has anything so big—or so rare—been hoisted onto the *Intrepid.* Employees of Weeks Marine, the crane operator, are crawling over the A-12's broad, smooth back, checking and securing the three attach points just inboard of the two engines and aft of the cockpit.

At 11:00:30 daylight appears between the A-12's tires and the barge—Weeks Marine runs a tight ship. It takes only minutes to raise the aircraft, slung slightly nose-high, to flight deck level, and then the crane sighs and begins to rotate counterclockwise. For a moment it looks like the A-12 is dangling over the West Side Highway while a river of yellow cabs flows

beneath it, the drivers honking and shouting and oblivious to the huge black cloud wafting overhead.

The crane positions the aircraft 10 feet over the deck and comes to a stop. The A-12 rocks gently, then creeps clockwise for a moment. Crews manning yellow ropes attached to the nose and main gear haul mightily on the lines like fishermen wrestling with a trophy-size tarpon when suddenly the main gear rope snaps in two. A brief moment of panic ensues, but the fishermen fan out to grab the wings and aft end of the engines while a director stands at the edge of the deck signaling thumbs-down to the crane operator, who can no longer see his payload. It is 11:09 when he gently sets the Blackbird down.

Applause breaks out on the deck above, and the operator leans back in his cab and lights a cigarette. It's been a long time since anything landed on the *Intrepid.* But such an auspicious event does not impress a Manhattan cab driver, who hears of the lift later that day. "Jeez," he says, weaving in and out of traffic, "why don't they just fly it onto the deck like *real* men?"

—*Patricia Trenner*

Update

First Journalist in Space

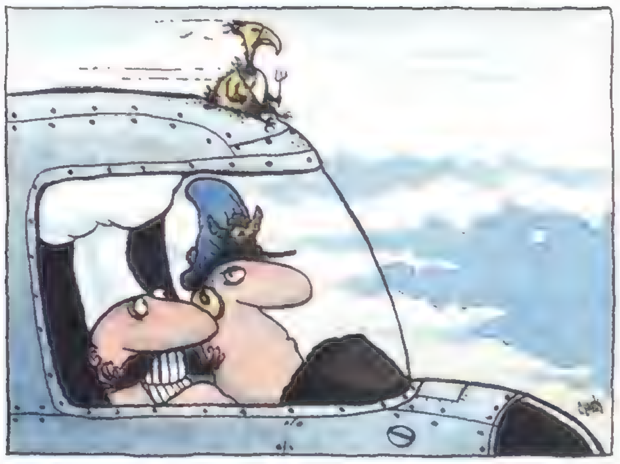
Japanese journalist Toyohiro Akiyama returned to Earth last December 10 after eight days in orbit aboard the Soviet Soyuz TM-11 and the Mir space station with a crew of two (Groundling's Notebook, December 1990/January 1991). The Tokyo Broadcast Service's 48-year-old "outer space correspondent" gave nightly reports on the physical sensations of spaceflight interspersed with wisecracks and good-natured complaints.

Fast Food

San Francisco sales manager Dan Lewis is a frequent flier. Like most who endure air travel, he labors to find the right words to describe airline food. "Weak, at best," he says after a pause.

Today, however, is different. Lewis is flying from Seattle to San Francisco on Alaska Airlines. He's just been served Oriental chicken salad, an artful concoction of marinated chicken, julienned red and yellow peppers, seasoned noodles, and sesame seeds. And now a chef wants to

DAVID CLARK



know how he liked it. "You enjoyed your meal?" asks a portly man wearing a culinary medal and a tall pleated white hat. "It was outstanding," Lewis says, somewhat taken aback.

Chef Wolfgang Erbe, a 40-year veteran of the restaurant, hotel, and catering trades on two continents, is now executive chef for Seattle-based Alaska Airlines. Last summer the airline revamped its menu under Erbe's direction, then sent him aloft to see how it was being received.

"The first time I looked down the aisle and saw all these people looking at me I thought, *My God, what have I gotten myself into?"* Erbe says. "First class was the worst—all those big shots. But now it's fun. People look at me and say, 'You're really the chef?' "

Erbe waits until passengers have finished their meals ("You don't want to bother a person who is eating"), then strolls through the cabin soliciting comments. Some passengers ignore him, but most seem delighted that someone actually cares about airline food. "The flavor was excellent, but the chicken was a little dry," one woman says earnestly. "You didn't finish your lunch," Erbe gently admonishes a passenger. "Oh, it was wonderful," she says. "I just wasn't feeling well today."

For the flight back to Seattle, Alaska Airlines' caterer has prepared, under Erbe's direction, poached king salmon with dill sauce, rice, carrots, and broccoli. The airline ties its meals to destinations: Oriental chicken salad for San Francisco, salmon for Seattle, fajitas and salsa for Mexican routes. "Alaska tells us to be bold, don't hold back," says Erbe, who's also served sliced pepper beef, Cajun crawfish, stuffed chicken breast with cream sauce, and venison brochette.

Erbe concedes there are limitations on how bold he can be. Flight scheduling and regulations dictate that nearly all meals be prepared 24 hours in advance, then chilled. And it's difficult to find a creative entrée that will appeal to 200 people. "You put down salmon and you're always going to have someone say 'I don't like salmon,' " he says with a shrug.

The salmon is a hit on the flight back to Seattle, with one passenger asking for seconds. But, as Erbe says, you can't please everyone. "You couldn't cut the carrots with a knife," grouses another.

—*Douglas Gantenbein*

Update

Lockheed Legend Dies

Kelly Johnson, designer of the P-38, F-104, U-2, and SR-71 and founder of Lockheed's legendary Skunkworks ("The Blackbird's Wake," October/November 1990), died last December 21 in Burbank, California. He was 80.

Mapping Mars

When Viking 1 approached Mars in 1976, the probe had to contend with the possibility of engineering failure, dust storms, and a variety of other threats. But the most serious was Big Joe. This 10-foot boulder, which the probe barely missed, could have sent the craft sprawling into the red Martian dirt of *Chryse Planitia.*

Viking didn't crash (see "The Case for Life on Mars," p. 63). In fact, the plucky spacecraft sent back thousands of pictures currently being studied at the Center for Earth and Planetary Studies at the National Air and Space Museum. The center's mapping team—Bob Craddock, Ted Maxwell, Mike Tuttle, Tom Watters, and Jim Zimbelman—is studying areas of Mars that have high scientific interest and making maps of potential landing sites for a future mission to Mars.

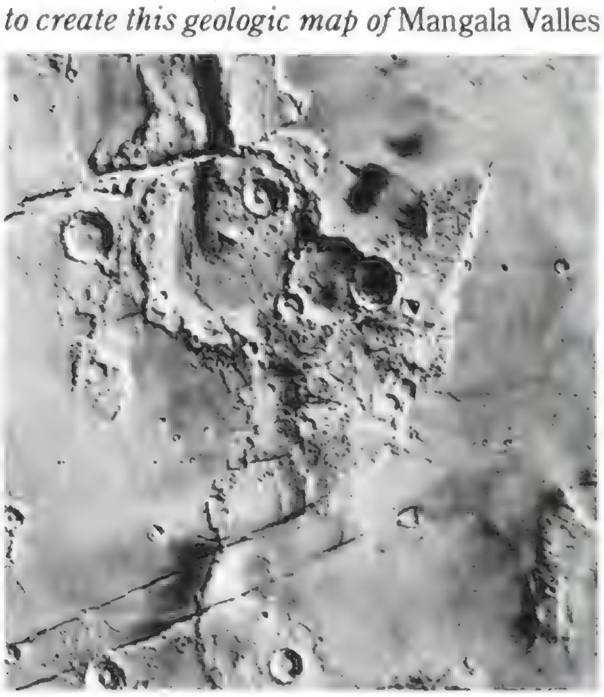
"I look at those pictures that we got back from Viking 1 and I can almost see myself on the surface wanting to walk over the horizon and see what's on the other side," says Craddock. *Chryse Planitia* (Greek for "plain of gold") teases the imagination because, except for its salmon pink sky, it doesn't look much different from the Mojave desert. Water may once have flowed in this semi-circular basin, so it's a promising place to search for fossils.

One of the most intriguing areas under investigation is an area called *Tharsis Montes.* It includes three of the highest volcanoes in the solar system: *Arsia Mons, Ascraeus Mons,* and *Pavonis Mons.* These 12-mile-high volcanoes share some characteristics with the much smaller volcanoes of Hawaii.

A NASA-supported Planetary Image Facility, the center assembles Viking photos into photo mosaics during the mapmaking process. This used to be a cut-and-paste operation, but "now that can all be done within a computer," explains Watters. "A lot of the seams can be removed or filtered out by adjusting the brightness and contrast across the frame."

The center's geologic interpretation of Mars and its detailed mapping contribute to a better understanding of the origin and evolution of the Red Planet. The new maps represent a seven-fold improvement over previous maps, and this is just the beginning. "Mars Observer will go down to one-meter resolution," says Watters, which means that an object the size of an office desk will be visible on the Martian surface. Future landers should have no problem steering clear of other Big Joes.

Viking Orbiter photos (left) allow the Museum's Center for Earth and Planetary Studies to create this geologic map of Mangala Valles *(right).*



U.S. GEOLOGICAL SURVEY

NASM

CAROLYN RUSSO

Fleet Pilots

From a pilot's perspective, the flight deck of an aircraft carrier looks not much bigger than a postage stamp. Visitors at the Museum now have a chance to see that for themselves when they try out a new hands-on exhibit in the Air-Sea Operations gallery. The exhibit allows prospective pilots the chance to "catch a wire" on the deck of a simulated carrier, with approaches ranging from the beginner's level all the way to night landings.

The exhibit was produced by ECC International Corporation and Evans & Sutherland under the supervision of E.T. Wooldridge, assistant Ramsey Fellow and curator of the gallery. Wooldridge, who flew F-4 Phantoms off carriers in the early 1970s, is pleased with the exhibit, but he adds: "There's an intangible that is totally missing. You know that there's no way you're going to get in trouble with that simulator—it's a game."

—*David Savold*

Artifacts

Lindbergh's view of the Spirit of St. Louis' *cockpit.*

Charles Lindbergh visited the Spirit of St. Louis *on several occasions after he donated the airplane to the Smithsonian Institution in 1928. This recollection of one visit is taken from the March 1, 1940 entry of* The Wartime Journals of Charles A. Lindbergh.

I was anxious to get in the building without being recognized, so after leaving the taxi I walked around the building in the hope of finding a side door open, but there was none. A dozen or so people were sitting on the benches on each side of the front entrance, watching all passers-by. Another dozen, including guards, were inside the door where the plane is hanging. However, by blowing my nose at the right moment, I got by them all. I did not want to have to talk to the guards, be taken to call on the museum officials, and look at my plane with a crowd of people gathered around.

Immediately after entering, I turned right, into the room of Presidents' wives and dresses. I never thought I should have such a close personal debt of gratitude to Martha Washington, but her dress and figure, and the glass case which contained them, were in exactly the right position for me to stand behind and look through into the adjoining room at the *Spirit of St. Louis.* No one took notice of me there, for if they looked at all it was at Martha Washington's dress, and not at me. I felt she and I had something in common as we watched the *Spirit of St. Louis* together. I rather envied her the constant intimacy with the plane that I once had.

How strange it seemed, standing there looking at the plane, and what a chasm of time and circumstances separated us. Yet in another sense how close we still were! I could feel myself in the cockpit again, taking off from the rain-softened runway at Roosevelt Field, skimming low over the waves of mid-Atlantic, or brushing past a high peak of the Rockies. Such a little plane, it seemed to me today; I felt about it as I once felt about the old Wright biplanes. Still, there was a trimness about the *Spirit of St. Louis* that even now gives me a feeling of pride. I felt I could take it down from its cables, carry it to some flying field, and feel perfectly at home in that cockpit again. (I have, in my dreams, flown the old ship several times since that last landing on Bolling Field in 1928, and I have always felt worried, and sorry I had taken it from the museum lest it crash in that post last flight. I was always relieved when I woke and found I had not really violated my decision that the plane should never be flown again.)

People stopped beneath it as I watched, and looked up at the plane and at the articles of equipment in the showcase. The plane is in excellent condition—perfectly cared for. I stood looking at it for nearly an hour, I think, losing all count of time. Finally, I noticed two girls looking at me—they were not certain—in a moment they would ask. It had been the most pleasant visit I had ever made to the museum—the first one on which I could really think about and appreciate my old plane. I did not want to talk to people. I left.

Museum Calendar

Except where noted, no tickets or reservations are required. Call Smithsonian Information at (202) 357-2700 for details.

Film Series "Metal Men of the Movies": *Saturn 3,* February 8; *The Black Hole,* February 15; *Back to the Future III,* February 22; *The Hunt for Red October* (admission: $1), March 1. Langley Theater, 8:30 p.m.

February 2 Monthly Sky Lecture: "Exploring the Planets." George Hastings, educator. Einstein Planetarium, 9:30 a.m.

February 5 Black History Month Lecture: "Benjamin O. Davis, American." General Benjamin O. Davis, U.S. Air Force (ret.). Langley Theater, 7:30 p.m.

February 13 Exploring Space Lecture: "Star Search: Infrared Scanning Techniques." Chick Woodward, University of Minnesota. Langley Theater, 7:30 p.m.

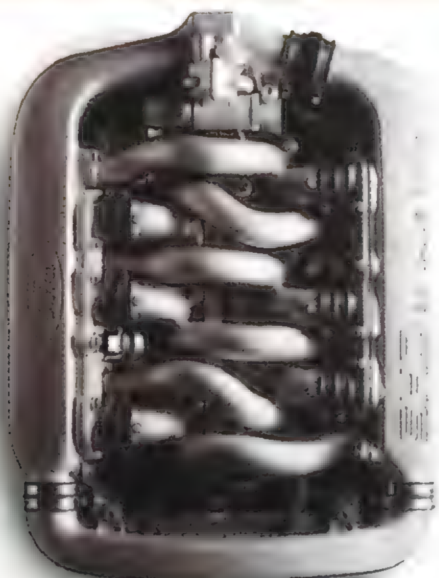
February 21 General Electric Aviation Lecture: "Air Tactics: From the Ground Up." Christine Fox, Center for Naval Analyses and consultant on *Top Gun.* Langley Theater, 7:30 p.m.

March 13 Exploring Space Lecture: "Inflation?" Kenneth Brecher, Boston University. Einstein Planetarium, 7:30 p.m.

March 21 General Electric Aviation Lecture: "Flying Back in Time." Cole Palen, pioneer aircraft expert. Langley Theater, 7:30 p.m.

Planning a Smithsonian Visit? The Associates' Planning Packet is yours for the asking. Send a postcard to Associates' Reception Center, Smithsonian Institution, Washington, DC 20560, or call (202) 357-2700. Hearing-impaired visitors can use TDD and call (202) 357-1729. Begin your visit at the Associates' Reception desk, located in the Smithsonian Castle.

Museum Hours Most Smithsonian museums are open 10 a.m. to 5:30 p.m. daily. The Smithsonian Castle, which has reopened with the new Smithsonian Information Center and Associates' Lounge, is open 9 a.m. to 5:30 p.m. daily.



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The Battle of Wyndham

On a recent visit to the Australian War Memorial in Canberra, I was disappointed to find no mention of the Battle of Wyndham. Disappointed, but not surprised. The only mention of Wyndham I've ever come across is in *The Army Air Forces in World War II,* which states that as of March 1942 the Chiefs of Staff in Washington were advised that the Japanese "might attempt at least the occupation of such points on the mainland as Darwin, Wyndham, and perhaps Townsville." Those of us in Wyndham at the time were of the same opinion.

Fresh out of flying school, I arrived in Melbourne on February 2, 1942, as part of the Hamilton Field Air Corps Combat Team, an impressive name for an unorganized crowd of inadequately trained fighter pilots. I had barely four hours in the P-39 Airacobra and had never even fired the guns. But we were welcomed with open arms and Australian champagne flowed in the Embassy Club for five glorious nights. *If this is war,* I thought, *it might not be so bad after all.*

On Day 6, I was given a special assignment: Wyndham. I was to run refueling depots for fighters that were to be ferried from Melbourne around the west coast and up to Java. I would be billeted with 6,000 Royal Australian Air Force troops already stationed at Wyndham. The first lieutenant who gave us our orders didn't have a map, but he thought that Wyndham was somewhere near Darwin. If I needed anything, he said, I should just call.

The next morning we boarded a train of ancient wooden cars. We crept north to Alice Springs, where we transferred into the backs of straw-filled trucks. Back then the Stuart Highway was merely a bulldozed path through 670 miles of the Northern Territory's roiling dust, relentless flies, and 109-degree heat. We boarded cattle cars at Larrimah for the remainder of the trip to Darwin, which covered 2,100 miles and took eight days.

I was amazed to learn that none of my eight men had any equipment except the clothes they were wearing. Under the impression they were going on temporary guard duty in Melbourne, they had left everything behind. We obtained sun helmets, mosquito nets, and some ill-fitting G.I. clothes in Darwin, but no firearms or maps.

My troops were a motley crew. One had been running moonshine in North Carolina before the war, another had been demoted for assaulting an officer, and a third had enlisted fraudulently, having served time for forgery and theft. I had a petulant shoe salesman from St. Louis, and with the exception of one good mechanic, I suspected the rest had been unloaded by a sergeant cleaning house. As their commanding officer, I was no bargain either. Nothing in my flight training or the New York art school I attended for four years had prepared me to command troops. I worried about the problem of discipline: What could I threaten these guys with that was worse than what they already had?

The pilot who flew us from Darwin to Wyndham told me it was a small port on the Timor Sea about 250 miles southwest of Darwin. Its only attraction was a meat processing plant to which outback ranchers drove their cattle to be slaughtered and shipped to England and the Philippines.

When we landed, everything but the runway was under water. Three surprised RAAF men waded out to meet us—we were not expected, and they knew nothing of the 6,000 troops the lieutenant in Melbourne had told me were there.

We moved our gear into a large hut with a number of double-deck bunks. Another room held a supply of canned goods, but the RAAF corporal said these were emergency rations; he had been buying daily supplies in town. We would do likewise. That afternoon we walked the seven miles into Wyndham, which comprised a few houses, a store, a rundown but rather splendid Victorian hotel, a dock, and the meat factory. At the end of the main street, which was surfaced with glaring white crushed shell, stood a fat baobab tree. From a distance it appeared to be laden with huge white blossoms, which suddenly all took flight—white cockatoos.

In the hotel bar a group of villainous looking men were swigging beer from quart bottles and playing billiards, and their stares clearly read *Who the bloody hell are you?* We retreated to the store, where staples were in short supply, with the exception of pickles and chutney labeled in Chinese. I bought some weevil-infested flour, canned goods, and sugar, paying for them with my own money at exorbitant prices and wondering how long I'd last before payday.

The postmaster, a thin, graying man with a salt-and-pepper mustache, told me it was impossible to telephone or telegraph Melbourne—thanks to the heavy rains, all the wires were down. In charge of arms and ammunition for what he called the home guard, he loaned us some bolt-action World War I Enfield rifles.

Back at the airfield I learned that the RAAF was expecting the steamer *Koolama,* en route from Darwin, to arrive with all sorts of supplies. The next day, however, the radio operator received a message that Darwin had been hit by a massive air raid. And the day after that a strange aircraft circled Wyndham at high altitude, then hurried off. We dug slit trenches in the soft clay, but a week later the heat had crumbled the walls.

Despite the flooded field, it never rained during our stay—we had just missed "the wet," the 40 inches that had fallen the previous month. Army men usually complain about the lack of hot water; in Wyndham we had no cold water. Our water tank stood in the brutal near-equatorial sun all day, and at night the rocky hills ringing the base threw off the heat they had absorbed. We had weevils in our bread, spiders in our bedding, snakes in the woodbox, and ants everywhere. Everything we owned either mildewed, rotted, or was eaten by insects. At dawn the flies descended in droves; at night the mosquitoes sang us to sleep.

A large dump of bright red 50-gallon barrels of aviation fuel, hastily unloaded by a U.S freighter shortly after the bombing of Pearl Harbor, made a wonderful target. It had to be moved, so we appropriated a 1932 Dodge wagon with flat tires and a dead battery that had belonged to the

Perth-Darwin air service. Dispersing hundreds of gasoline drums via station wagon and camouflaging them under trees was backbreaking work, but at least it was something to do.

And where were the aircraft we were assigned to service? Late one evening a decrepit U.S. B-18 bomber, obsolete before the war started, came in to land. The pilot had gotten lost en route to Brisbane and was nearly out of fuel. It turned out he hailed from a town not 60 miles from my hometown in Nebraska, but he had no desire to hang around and chat—he left immediately after we refueled his airplane. We hated to see him go. It was the only U.S. aircraft our detail ever serviced.

Like the Aussies, we pinned our hopes on the *Koolama* and all the wonderful things we imagined she bore—food, tools, maybe even one of those new-fangled Jeeps. She creaked into Wyndham one afternoon with a skeleton crew, listing, full of holes, and leaking badly from a Japanese attack.

The next morning we went to see what could be salvaged, but the crew were still asleep so we headed back to the airfield. Just outside of town we spotted a small RAAF biplane headed in the same direction. Further on we heard the roar of several aircraft. One of them tilted in the sunlight and plunged into a steep dive. Then came a tremendous explosion followed by several smaller ones.

From a rise we could see that what was left of the gasoline dump was aflame. Fifty-gallon drums flew high into the air. Two fighters droned above the airfield. Suddenly six more came over the hills, right on the deck, heading in for a pass. Without ever having attended an aircraft identification class, I knew they were Zeros.

Something on the field exploded with a huge roar. One of the Zeros pulled up from his pass in a languorous turn right over our heads, so low I could see the pilot's face. Angry and frustrated, I fired one shot with my home guard rifle. The Zero did not fall instantly to earth—rather, it and the others continued to rake the field at their leisure until they grew bored and whined off toward the coast.

The field was a shambles, but no one was hurt—most had taken shelter in a ditch. Miraculously, the radio shack was untouched. I sent an urgent message to headquarters, something to the effect that the situation was untenable and required immediate relief.

The next day, as we set about repairing our slit trenches, the postmaster drove out to report that the *Koolama* had rolled over and sunk during the night. Nothing had been salvaged from her cargo. Declaring an emergency, we broke into the storeroom of rations. No prizes there: tinned mutton, bully beef, tomatoes, and hardtack of a consistency that made it useful only for starting fires.

And so we waited, fitfully. We half-heartedly moved the remaining gasoline drums, but no one believed we were doing anything truly useful. Someone pointed out that the mud flats, dried out and baked by the sun, made the entire airfield a huge runway for Japanese transports. We hid drums of gas and a supply of food in case we had to "go bush," a rather grim prospect.

While we waited for relief or attack, the postmaster got a message from the Australian government ordering the dynamiting of the meat plant and water supply and the evacuation of Wyndham, but nothing ever came of it. The air service arrived to evacuate some women and children and deliver a letter to me. My men gathered around to hear the word from headquarters, which turned out to be Precautionary Instructions in the Event of Capture by the Enemy. It was a great morale builder.

Engineering troops arrived with orders to mine the runways. We suggested that to effectively dissuade enemy aircraft from landing, they would have to mine the mud flats as well, a task comparable to mining the vast Nullarbor Plain. They had their orders, they said. They left one runway open and departed.

Eventually the postmaster drove out to say the latest radiogram from Melbourne ordered the evacuation of my detail. When a flight arrived a half-hour later there were last-minute snags: the pub owner followed us to the airplane brandishing a £30 tab for whiskey. I suggested he take the matter up with Melbourne. Then one soldier said he didn't want to fly on an airplane with 13 passengers. I gave him permission to stay behind, but he changed his mind. At last we climbed aboard and bid farewell to Wyndham.

And so it ended. By the time we reached Melbourne we had traveled 7,000 miles by train, truck, and ship to fuel one lost airplane and hide a few barrels of gas. I rejoined my group in Sydney and was later sent to New Guinea, where I flew 160 combat missions, but I never felt so in the thick of it as I had firing one shot from my antique rifle in the Battle of Wyndham.

—Major Robert Pierce
U.S. Air Force (Ret.)

Spaced Out

DAVID CLARK

By now, citizens of even pre-industrial, pre-electronic, pre-TV-syndication cultures (if there are any left) have learned that when prompted with the word "space," the proper response is "the final frontier." Not that they know what it means. But then, I've pretended all my adult life to understand "habeas corpus," and no one's called me on it.

Americans, however, know all too well what "final frontier" means. To those of us old enough to remember both Davy Crockett (the TV show, not the individual) and JFK (the president, not the individual), that phrase, uttered with atypical Shatnerian restraint, suggests a bushy-haired Harvard guy driving a covered wagon across a sage-dotted prairie. He's looking for a fantastic new reality commensurate with his Ivy League-nurtured imagination, but all he's going to find is Nebraska—and that's Final.

Thus the possibly tragic, certainly annoying contradiction of space: it promises so much yet delivers so little. For me, the promise was first made in elementary schoolboyhood when a poster appeared on my bedroom wall depicting, well, outer space, as it were. I vaguely recall an artist's rendering of space stuff that the poster implied was even then nearing deployment: a space station, spacesuit, and interplanetary rockets, rendered in vivid colors against a white-on-black background of galaxies, nebulae, and comets. It was this poster, as well as the sci-fi novels I began to read around then, that defined "outer space" for me.

It was a lot jazzier and more fun than any boring old "final frontier." Space was a place (sounds like a hardware store jingle, I know, but what doesn't these days?) where everything was fabulous. The spacesuits, particularly as described by Robert Heinlein in *Have Space Suit—Will Travel,* were mammoth and bulky but also cozy, protective, and equipped with everything you needed for that self-sufficient, ready-for-anything feeling that came, in real life, only from sneaking snacks into your room.

The cylindrical spaceships and toroidal space stations were like toys, simple shapes painted in glaring primary colors. The message: in space, everything would be new, which meant that everything would work, which meant that everything would be A-OK. And we would be among friends. The planets themselves, with their distinctive coloring and assorted sizes, formed a sort of mute cartoon family, with Jupiter the daddy, Saturn the mommy (complete with wedding ring), Mercury and Pluto the babies at the peripheries, and Earth the best, of course. You recited "Mercury, Venus, Earth, Mars" with the singsong jump rope rhythm reserved for "Larry, Moe, and Curly" and, later, "John, Paul, George, and Ringo."

If space was at all scary, it was scary in a fun way, offering monsters that could be destroyed with impunity—in sharp contrast to angry teachers or parents, which could not. And because space was infinite in both time and distance—or so one quaintly thought at age 12, before the hegemony of the Big Bang theory and "the inflationary model" of the universe—literally anything could be out there. Not only thought-beings, protean shape-shifters, clouds of pure energy, and other tired old S.F. warhorses, but *anything.* And of course if anything *was* out there, anything could one day come here, either to conquer Earth and subjugate humanity (which would serve one's parents right) or to enlighten mankind and banish hate, war, prejudice, injustice, and homework. In the absence of evidence to the contrary, space was a combination of heaven, storybookland, and amusement park.

Then came evidence to the contrary. *2001: A Space Odyssey* showed that while in theory space might be finite in duration and extension, it was in reality infinite in tedium. The mere act of docking your (unsleek, stick insect-like) spacecraft could take a lifetime. Add to that the absolute cold, the grossly inhospitable behavior of black holes, and the random *zing* and *ping* of micrometeoroids and gamma rays, and space begins to seem downright hostile. And the distances! It's one thing to fantasize contact with extraterrestrials. It's another to realize that, even if an alien culture was discovered as near as five light years (in galactic terms, across the hall), the most rudimentary exchange ("Hi, how are you?" "What?") would take 10 years—bad news for a civilization that gets antsy when put on hold for 15 seconds.

Let's face it: there's no life on Mars, the moon landing was a letdown, the shuttle's become a crapshoot, the Hubble changed overnight from astronomical milestone to sitcom episode ("Thursday: Tempers flare at Ground Control when the mirror shows signs of imperfections! Ed Asner has . . . Hubble Trouble!"). Everything may be new, but everything does not work, and everything is not A-OK.

Oh, space is still the big time. The brain-crushing fact that we are surrounded by millions of—forget stars—galaxies is enough to suggest that there is still plenty of *there* out there. It's just that now it seems hopelessly remote. Space itself may be unchanged, but its meaning has shifted. Infinite possibility has given way to perennial disappointment. Still, I try not to be bitter. After all, space consists of only three dimensions. There is a fourth left to explore. I'm looking forward to Time: the *new* Final Frontier.

—Ellis Weiner

THE ROCKET RANCH GANG

They're at home on the range, where seldom is heard a discouraging word and the ranch hands build rockets all day.

by Ed Regis *Photographs by Cindy Charles*

At the bottom of a canyon in northern California, some enterprising space cowboys have been taming a new frontier: personal rocketry. To hell with an official presence in space. These gonzo incarnations of Robert Goddard have spent the last two decades designing, building, and launching hundreds of their own rockets—and we're not talking giant firecrackers or toy models. These are rockets that have to be lugged out to the Nevada desert for launch, rockets that have traveled upwards of 20 miles. Air traffic control has to vector aircraft away from the area to keep them discretely out of range of the one-, two-, and even three-stage launch vehicles.

The rockets are all built at a 320-acre parcel of land known as the Rocket Ranch. It's a private retreat for personal rocketry or the wages of a hobby gone wild, depending on your perspective. Formerly used by the military as a practice bombing range, the property was put up for sale by the government in 1980 for $150 per acre. "We jumped at the chance," recalls Chuck Piper, one of a cadre of ten or so folks looking for a home for their rocket club. All employed in the aerospace and electronics industries, these anti-bureaucratic, anti-academia space rangers have built what's probably the world's only private, noncommercial rocket design, manufacturing, and test center.

"It's the only place in the county zoned for recreational rocketry," says board chairman Kurt Bohan. As such, the place attracts a certain amount of unwanted attention. "We've seen military helicopters land on the hilltops, stay there and look around for a while, and then take off again," Piper says. And what must the Soviets think about this remote site, which probably shows up on their satellite photographs?

To get to the Rocket Ranch you start at an intersection that's itself out in the middle of nowhere and drive west about 20 miles. You continue down a twisting mountain road until you emerge in open rangeland, where cattle and horses graze in sparse scrub. Eventually pine-studded mountains loom up on either side of the roadway, which parallels a dry stream bed.

Finally, you come to the gate. It's an ordinary chain-link gate but it's secured by a rack of no fewer than 10 padlocks. The Rocket Ranch is another mile or so beyond, down a small spur canyon.

When I arrive at the site, the membership is out in force. It's a picture-perfect, 102-degree day in the mountains, after all, so there they are, the all-stars of civil rocketry: Chuck Piper, a mechanical engineering graduate of the

University of California at Berkeley and currently senior ordnance engineer for Quantic Industries of San Carlos. There's smiling Kurt Bohan in his cowboy boots and straw hat, a guy who used to make satellite components for Ford Aerospace and now runs an engineering firm in Hayward. Here's Jerry and Sharon Durand, who operate their own electronics design company—Durand Interstellar—out of Los Gatos. And

Life on the ranch isn't all fun and games; the routine includes a fair bit of manual labor.

there behind the mirror shades is Ray Goodson, propulsion specialist at an aerospace firm in Sunnyvale and designer of the group's "nozzle-less" rocket motor (not literally nozzle-less, the thrust chamber is composed of solid fuel and burns away during launch).

And then there's the site itself, which is right out of *Dr. No.* The property runs from the canyon floor to the tops of the surrounding mountains and then some. Glancing upward you can see dirt roadways that zigzag up the red hills. The rim of the canyon is dotted with banks of sodium arc lights mounted on towers and aimed at the ranch below.

"At night when all the lights are going and there's a high-humidity fog," Piper says, "well, it looks like a scene from *Close Encounters.*"

"Except there's no music," adds Bohan.

"Yeah, we don't have an electronic organ," Piper says.

Off in the distance you can see tailings from an abandoned mine shaft. You can hear birds chirp and insects zing. A deep blue sky arches overhead, and you feel all at once that this place must really be a Secret Government Lab, that these people are CIA.

"Well, it would be nice if we were!" Bohan says when I tell him my impressions. "Because then we wouldn't have had to do all the work ourselves."

Indeed, these guys are the ultimate do-it-yourself space invaders. With the exception of some earth-moving work, which they contracted out, they did every last bit of the work themselves, while at the same time managing to comply with state and local building specifications.

"First there were the grading permits," Piper recalls. "We didn't know this when we bought the place, but in our county, in order to operate a bulldozer on your own property you need to have this grading permit, which costs $150. And you have to tell them ahead of time how much dirt you're going to remove, and what possible impact on the local ecology it's going to have, and so forth."

That, however, was only the beginning. The creek running through the property made for another headache, especially since it's usually dry: "We had to show that none of the buildings, structures, grading, roads, or improvements that we were going to make on the property would be endangered by a hundred-year flood," Piper explains.

So they did that too, all on their own. "We had to submit a hydrological survey and do a water runoff study," he says. "It took almost three months to do that, and we couldn't do anything with the property until we had it finished. We had to go out and take all sorts of measurements . . . and anyway we finally prepared this 25-page report and submitted it to the county."

The county approved the report and the space crusaders pushed ahead . . . until the restroom crisis. Since the Rocket Ranch was zoned "agricultural/recreational," it had to have restrooms equipped with all the usual niceties, and the whole thing had to be handicapped-accessible.

No problem! They'd do *that* themselves too. They designed and constructed a spiffy restroom, complete with showers, handicapped facilities and wheelchair ramp. To make things easy on themselves, they used a portable conveyor belt to transport the concrete blocks.

Often enough, though, a vast quantity of sheer physical labor was simply unavoidable, as it was when the time came to put in the water, sanitation, and electrical power systems, all of which went underground.

"There's approximately 63 miles of wire buried in the ground here," Piper says, looking off down the valley. "You can't see it, but it's here."

"It took about eight months of weekends to dig all this and put everything in," says Bohan. "Tom Pavia and I did most of it. We did it by hand, with pick and shovel—in the rain many times."

"We ran into rocks," Pavia says. "Lots of rocks. *Huge* rocks! You had to take a pick and hammer and break them

up. Just like we were prisoners."

"Yeah," Bohan says, "and our parents used to tell us that if we didn't get a good education we'd end up digging ditches!"

One of these ditches stretches some 900 feet up a steep hillside to a 2,500-gallon water tank. Underground pipes run from the tank down to a handful of fire hydrants located throughout the canyon at strategic points, one of which is the propellant mixing and casting building. This is the heart of the Rocket Ranch, where the solid fuel for the rockets is manufactured.

It's one of about a half-dozen steel-reinforced poured-concrete structures, which the rancheros put up themselves, of course, in most cases without needing to get building permits. "We made a number of our buildings just slightly smaller than the size for which you'd legally *need* a permit," Bohan says. "That's why a lot of them are little boxes: 10 by 12 feet or so."

Everything else here had to meet code. "All the lights are class I and II explosion-proof lights," Piper says, "so that if there's any vapor or dust around it's not going to ignite. We have lightning suppressors, we have electromagnetic noise filters at the blockhouse to screen out stray signals from power sources. Even though we're an amateur organization, all our members are professionals and we've done everything we can to make this the safest possible facility."

It's hard to argue with that. The controlroom blockhouse is a fortress with 18-inch-thick reinforced walls. Its windows, salvaged from surplus tanks, can withstand a direct hit from a shell. The explosives magazine is another stronghold, the door alone weighing 1,400 pounds. "It's made out of quarter-inch armor plate," Piper says, "and it's got four inches of steel-reinforced concrete behind it."

Another one of these little concrete boxes stores electrical equipment: countless oscilloscopes, high-speed chart recorders, television monitors, cameras, computers—everything but radar. All of it's courtesy of member Ken Kitlas, who gets most of it cut-rate at electronics swap meets in the Bay Area. On the shelf is a nuclear detonation profiling scope, one of Kitlas' big-ticket purchases—$25, marked down from 40.

The rest of the stuff was surplus from aerospace companies in the area. "Some of the prices were really incredible," Bohan says. "Those stadium floodlights up there," he says, squinting up, "they cost a couple of hundred bucks apiece when new. We got them from Lockheed for eight dollars each."

This is not to say that building the Rocket Ranch has been cheap. Treasurer Al Kraft estimates that the members have collectively laid out some $200,000 over the past 10 years in furtherance of their obsession. The money arrives in the form of $65 monthly dues,

Al Kraft and Tom Pavia rehearse pouring propellant into a funnel to produce a rocket motor.

THE CARS THE ESTABLISHM CAN'T BUILD

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In short, a sports sedan designed for full-fledged humans, instead of the one-dimensional version that conventional carmakers seem to have in mind.

The Turbo Convertible resembles no present-day car so much as the classic top-down roadsters that

*MSRP, excluding taxes, license, freight, dealer charges and options. 900 shown with optional light-alloy wheels and fog lamps. Prices subject to change. **Whichever comes first.

occasional special assessments, and contributions. Rumor has it that one year Piper put $10,000 of his own money into the Rocket Ranch. There have been costs in connubial harmony too, with other rumors abounding of "space widows"—spouses left in the lurch as members go off to build rockets all weekend.

As to the point and purpose of it all, everyone has his own opinion. One notion is that all this is done for educational purposes. "We want to have students get involved in this," says George James. "We'll have them build payloads for us—videocams that can go to 25,000 or 30,000 feet."

Another version is that the Rocket Ranch exists to pioneer new launch technologies. "This stuff is true high-tech," Piper says. "What we're doing is basically a low-cost version of what United Technologies can do. We've got vacuum systems, inert-gas systems, and so on. We're always trying out something new."

A third view is that they want to spearhead a grassroots human migration wave out into the cosmos. "Humanity has to leave the planet eventually," says Bohan. "Statistically, something will go wrong in the atmosphere no matter how much we try to avoid it. But if there's enough humanity outside, then things still go on. Going into space is a matter of survival in the long run."

True as all of that might be, none of it goes to the heart of what really motivates these folks. What's really behind the Rocket Ranch, the truth be told, is

Ken Kitlas' eye for bargains helps him round up second-hand electronics for use at the Rocket Ranch.

the sheer Joy of Rocketry—nothing less than the exhilaration of invading the universe with their own personal space hardware. What else could induce the ranchers to spend weekends, holidays, and vacations digging ditches in the rain? What else could account for all the money they pour into it? What else could explain the space widows?

"Job satisfaction in the aerospace industry isn't what it used to be," Piper explains. "If you went in to your boss and said, 'I'd like to build a 15-foot rocket that can go 20 miles for less than $5,000,' he'd just laugh. He'd rather put you to work on some small part of a big thing that costs a million bucks. You're just a small cog in a large wheel these days, and most people don't really get much satisfaction from that. But out here we can pretty much build what we want, when we want."

"And you actually get to be there when it's launched," adds Jerry Durand.

In fact, 1991 is a launch year, and the ranchers will soon be building their rocket motors again. They start from scratch, using chemicals such as ammonium perchlorate, potassium perchlorate, and potassium nitrate. They place these and other herbs and spices into metal bowls and stir with stainless steel helical blades, not unlike making a cake batter. Then they pour the mixture into a vacuum casting bell—an aluminum cylinder with a plexiglass lid—which in turn is placed inside a concrete-walled enclosure. The casting bell has a funnel on top, and as the rocketeers dump the mixed propellant into the funnel, they can observe what's going on through the plexiglass lid. Eventually, all of this mixing and stirring will be done by remote control from the blockhouse, with closed-circuit TV.

"Why?" I ask. "Is this *dangerous?*"

"About as dangerous as driving out here," Piper says, not too reassuringly.

At any rate, the propellant casting is then left to harden, a process that takes a couple of days. Later, the result—a solid-fuel rocket motor, which now has the look and feel of an extremely large pencil eraser—is moved over to the stripping pad and trimming station, where it's finished off. Finally, the surface is covered with a chemical inhibitor to keep it from accidentally igniting, and the finished unit is placed in the explosives magazine for storage until it's ready for launch.

When launch time rolls around—traditionally it's scheduled for three-day weekends like Memorial Day and Labor Day—the members abandon the ranch for an even more remote site. Rocket motors, housings, and other parts are crated, packed into cars and trucks, and driven east on a 400-mile trek. This drive has occasionally made for some problems, like the time the transmission burned out on the main rocket transport vehicle, which is in fact a two-ton flatbed truck belonging to Piper. Fortunately Piper is also a regular Mr. Screwdiver, and he was prepared for the emergency.

"I bought a transmission a couple of weeks earlier because the old one was making weird noises," he remembers. "But I didn't have time to change it beforehand, so just as we were going out the driveway I said to myself: *Well,*

maybe I ought to take this extra transmission along, just in case. And as we were coming down over the pass outside of Truckee, all of a sudden it started making just the most godawful grinding, grunting, growling noises you ever heard. Smoke started coming out from underneath the truck . . . and anyway, between the grinder, the acetylene torch, and the generator set that we had with us, plus the floor jack that I had, plus sledgehammers, we pounded the old one off and put in the new one."

Finally, they arrived many hours later at the launch site, which is a dry lake bed in Nevada's Smoke Creek Desert, about a hundred miles north of Reno. The place is surreal.

"Terrible conditions out there in the desert," one of the launchers says. "It's not a good environment to build things. Lack of power, lack of sanitation, lack of everything."

"It's like being on the moon," says another member. "Only you don't have to bring oxygen."

"It's like being on Mars," says another.

Actually, it's like being in the most out-of-the-way place in Nevada, which is bad enough. A flat hardpan desert crisscrossed by ruts and tire tracks, the site is completely surrounded by low mountain ranges off in the distance. The members show up here in their Suzuki Samurais, Ford Broncos, and assorted other four-wheel-drive vehicles. They pitch tents, unfold sleeping bags, and drag out Coleman stoves. Once they have climbed into white coveralls and donned hardhats, they assume identities as range safety officer, communications chief, or some other elder—all of them wearing color-coded badges just like NASA's.

"In the old days," Bohan says, "it was a lot more informal. During those years a few people made their own fireworks and would set them off between launches. There was this one fellow I remember, a really heavy-set guy, he was apparently looking into the fireworks box using a flare to see what was in there when some sparks dropped in

It's do-it-yourself time as Chuck Piper adjusts the stadium lights that extend the workday.

Intergalactic headquarters and the test site share the bottom of this rocky canyon with the ranch's blockhouses, bathroom, cargo container, shop area, and utility yard. But to reach the canyon you must first pass though the front gate (below), well secured with padlocks.

from the flare, and he made a hasty retreat just as the box was going off."

The granddaddy rocket to date has been Piper's own 22-foot-long, three-stage masterpiece. Launched in 1976, it went up like a dream. The first stage burned for one and a half seconds, developed 7,000 pounds of thrust, and took the rocket to 1,500 feet. It coasted for a second or two as the first stage cut out, then the next stage fired and separated from the booster.

The second stage burned for eight-tenths of a second and developed 4,700 pounds, which took the rocket to 5,000 feet. By that time it was already out of sight except for a curling trail of white smoke.

Then the third stage cut in. A small engine with only 400 pounds of thrust, it burned for a full 15 seconds and climbed up to where the sky's a deep purple. The rocket eventually reached an altitude of 120,000 feet.

Before long another rocket will stand alone on the launch stand, shimmering

The gang's all here: Standing (from left) are Sharon Durand, Jerry Durand, Tom Pavia, Chuck Piper, and Al Kraft. In front: Doug Royce, Kurt Bohan, and Ken Kitlas. Before long they'll be back at their launch site in the Nevada desert (below).

slightly in the desert heat. On a good day as many as 10 rockets might be sent up. After the final launch, at sundown, it will be time once again for "The Last Dead-Dog Campfire Party." It's a traditional ritual, although not as raucous as it sounds. How rowdy can a bunch of engineer types get after firing rockets into the blue all day?

If the post-launch blowout doesn't exactly live up to its billing, it's partly because these rocket ranchers are already thinking about next time. Their latest goal is an altitude of 100 to 300 miles—or higher. "Our board of directors," Bohan says, "has officially and unanimously voted to develop minimal orbital technology."

COURTESY ROCKET RANCH

Minimal orbital technology. In other words, these guys have it in their minds to lob something into Earth orbit. What that something *is* really doesn't matter—payloads have never been their strong suit—just so long as it circles Earth for a little while. Their own personal Sputnik.

An improbable enterprise to be sure—there's the guidance problem to be solved, for one thing—but nothing this crew can't handle. They're already talking about *methods,* about this technique they have in mind for spin-stabilizing the craft, when I ask if they have a timetable for all this.

"You mean like 'by the end of the century?' "

Everyone laughs. But then they all agree. Why not? That's *ten years away,* after all! *Plenty* of time!

"Yeah, up to orbit for sure," they say. "By the end of the century."

THE JOY OF RIVETS

SOME MUST BUCK WHILE OTHERS SHOOT

by O.H. Billmann

Most airplanes are held together by thousands and thousands of rivets. It takes 2.5 million of them to tack down the skin on a single Boeing 747-400. So perhaps a sheet metal mechanic can be excused for viewing an aircraft as little more than a huge number of rivets flying in very close formation.

CAROLINE SHEEN (4)

This mundane fastener has borne the test of time. It is dirt-simple, inexpensive, and, in the hands of a pair of skilled workers, can join metal quickly. In today's aircraft plants, automated equipment does most of the riveting, and the old-fashioned manual method is reserved for one-of-a-kind jobs like repairs, modifications, and putting together prototype aircraft. In the days before robots, though, riveting departments employed hundreds of people for the demanding job of assembling airplanes.

Manual riveting usually requires a team of two. One drives ("shoots") aluminum alloy solid-shank rivets into one side of the aluminum panels with a pneumatic gun; the other backs them up ("bucks") on the other side with an iron bar that weighs from two to six pounds. The idea is to evenly deform the end of the rivet's shank so that it will hold the sheet metal together permanently. If a rivet is not driven against the bucking bar long or hard enough, the shank will not swell sufficiently and the rivet will be insecure—"underdriven." If too much pressure is applied, however, or if the gun is adjusted too high, the rivet will be overdriven, which is also an insecure and low-strength condition. Rivets can also be poorly set if the gun set is tipped, if the bucker controls his bar poorly, or if he uses a bar of the wrong size and weight. At the very least, loose rivets invite corrosion; at the worst, badly driven rivets can turn a flight into a disaster.

In aircraft construction riveting becomes an art form, and the artists who perform it must harmonize well. I've observed thousands of aircraft assemblers pounding millions of rivets. Most are quite good, particularly when teamed up with competent partners. A good team can drive 5,000 rivets a day. But occasionally a

mismatched pair is thrown together by production pressures. I've seen fights break out over a shooting technique that inflicts undue pain and suffering upon a bucker. Wing, fuselage, and human skins have suffered grievous damage due to a miscommunication between shooter and bucker. And shooters have nearly lost their minds trying to cope with insensitive buckers.

Usually the shooter works on the outside of the aircraft while the bucker works on the inside. Communication between the two is essential but cannot be easily accomplished verbally. Instead, sounds and signals suffice, transmitted by both rivet gun and bucking bar. It's a sort of Morse code that depends on the number of dits and dahs as well as their amplitude.

Rivet guns are driven by air pressure. When the shooter pulls the trigger, short bursts of air hit the rivet set, a machined-steel collar inserted in the gun barrel that engages the rivet head. This produces the machine gun sounds of the riveting operation. If the bucker inside the aircraft does not have the bucking bar properly positioned, the impact of the rivet set can dent the thin skin. Therefore, it's vital that the shooter knows his counterpart has his bar firmly on the rivet end before he pulls the trigger.

Generally, the shooter puts a rivet in a hole, then places the set of his rivet gun against the rivet head and gently pulls the trigger. This results in a light *tappity-tappity-tappity* that serves two purposes: it allows the bucker to locate the rivet by sound, and it permits the shooter to discern the hollow sound changing to a solid one when the bucker gets the bar squarely against the rivet.

When the bucker finds the rivet and gets the bar against it, he signals the shooter by pushing up on the rivet a little. The shooter feels the rivet move and presses the gun firmly on it. The experienced shooter, knowing the power of the particular gun, depresses the trigger for a period that he judges to be just right for the size and strength of the rivet: *dat-dat-dat-dat-dat-dat.* Since the shooter is unable to see the bucked end of the rivet, he waits while the bucker checks it, often with an inspection mirror when the rivet is in an inaccessible location.

If the bucked end is precisely deformed, the bucker bangs his bar on the rivet twice: *thump thump.* However, if the rivet is underdriven, he bangs it once: *THUMP.* The shooter responds with another *dat-dat-dat-dat,* then pauses for another inspection. If it is still underdriven, the bucker *thumps* it again, but gently, which elicits another *dat-dat.* If all is now well, the response from the bucker is a solid double bang: *THUMP THUMP.*

But if the rivet is overdriven it must be drilled out and replaced, a tedious and embarrassing task for the shooter. The signal for a rivet that is mashed or otherwise unacceptably distorted is three loud and disheartening *THUMP THUMP THUMP*s.

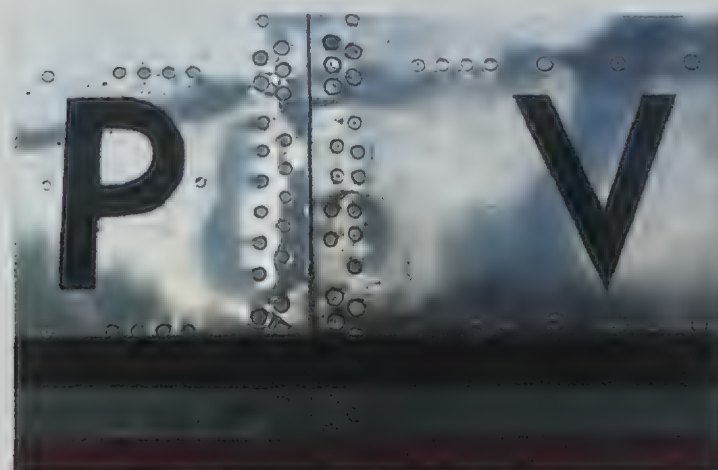
As a flight line crew chief for Douglas Aircraft in El Segundo, California, I observed a spectacularly mismatched riveting team one morning in 1949. Let's follow them as they repair a leading edge wing skin on a Douglas AD-2 Skyraider dive-bomber, damaged by a

chance encounter with a forklift.

The bucker has laboriously wormed his way into the wing through the fuselage. He is lying on his back while stiffeners and fasteners gouge his shoulders. He has a flashlight, an inspection mirror, an assortment of bucking bars, and the beginning of a splitting headache. When he has squirmed as close as he's going to get to the area to be riveted, he can just barely see daylight filtering through the rivet holes.

He raps one of the ribs lightly to signal his arrival. The shooter, who has been waiting on the wing, inserts the initial rivet into a hole and waits. The bucker fails to see the rivet shank in his darkened crawlspace and does not realize the shooter is ready and waiting. He thinks it is *he* who is ready and waiting. And so he waits, in silence.

The shooter impatiently removes his rivet gun from the rivet head at the instant the bucker finally sees it and eagerly slams his bar up against it. The unrestrained rivet flies out of the hole and hits the shooter squarely in the forehead. Irritated, the shooter attempts to insert another rivet in the hole, but the bucker still has his bar firmly plastered against the spot. The shooter applies more thumb pressure in a futile attempt to insert an aluminum rivet into a steel bar. The bucker, feeling the pressure and assuming the shooter



has the gun on the rivet and is about to drive it, enthusiastically pulls back and slams the bar against the rivet shank, nearly fracturing the shooter's thumb. The shooter storms off the wing as the bucker bangs on the loose rivet, popping it out of the hole again.

"What are you *doing?*" the shooter yells, addressing the bucker's shoes. "What?" comes the reply from deep within the wing. "I said, What are you *doing*? You keep shoving the rivet out of the hole! Just wait until I start tapping on it with the gun before you push up on it, understand?"

But he doesn't understand. All he could hear was "What are you doing?" The rest is unintelligible. Anyway, he knows what *he* was doing. In his opinion, it's the shooter who seems confused.

The still-seething shooter is now back on the wing, muttering as he inserts another rivet and begins lightly tapping it with his gun. The sound turns from hollow to solid—the bucker's bar is on the rivet. The shooter fires off a solid blast with the gun. Unfortunately, at the same moment the bucker slips off the rivet and the riveter ends up denting the unsupported skin. He stomps off the wing again and rushes over to the opening in the fuselage. Grabbing his partner by the leg, he bellows, "You're driving me crazy, for God's sake! Stay on the rivet! You've made me ding the skin!"

The bucker hears only muffled shouts. He lies on his back thinking about the painful crick developing in his neck.

After climbing back on the wing the shooter begins what he hopes will be a routine riveting operation. When he feels his partner push up on the rivet, he fires: *dat-dat-dat-dat-dat-dat-dat.*

THUMP comes the "underdriven" signal from inside the wing.

Dat-dat-dat-dat-dat the shooter responds.

After a moment, another *THUMP* echoes.

The shooter complies with another *dat-dat-dat-dat.*

Finally, after studious evaluation, the bucker issues a light *thump.*

The riveter carefully measures out a *dat-dat-dat.* After a protracted wait, a timorous *thump* is heard. The riveter, now severely agitated, replies with a dainty *dat-dat.* The response is a very faint *thump.* The shooter disgustedly squeezes off a single, infinitesimal *dat.* And then, the bucker waits one perfect beat before replying with a resounding *THUMP THUMP THUMP.*

The shooter explodes. "Drill it out? Drill it *out?*" he screams. "How could just one little *dat* make that much difference? And how could lacking that miserable little *dat* make it underdriven? I'm going to come down there and *murder* you!"

Not hearing a word but knowing full well that his last signal would inspire a towering rage, the bucker has already extricated himself from the bowels of the wing and is in full flight across the ramp.

Since the bucker has jumped ship and his riveter is sulking in the smoking area, another team is sent out to complete the job. I assume it's a couple of pros who will finish this task neatly and efficiently.

After the new bucker, who is much more

compact than his predecessor, snakes into the wing, the burly new shooter crawls up on the wing with a 4X rivet gun. He is brandishing the big gun like a Buck Rogers Rocket Pistol. A 4X gun, which drives 3/16-inch-diameter rivets, is much more formidable than the 2X gun the previous riveter had employed. Using a 4X gun on this job is like shooting quail with an anti-aircraft gun. From a ladder under the engine cowling, I watch with some apprehension.

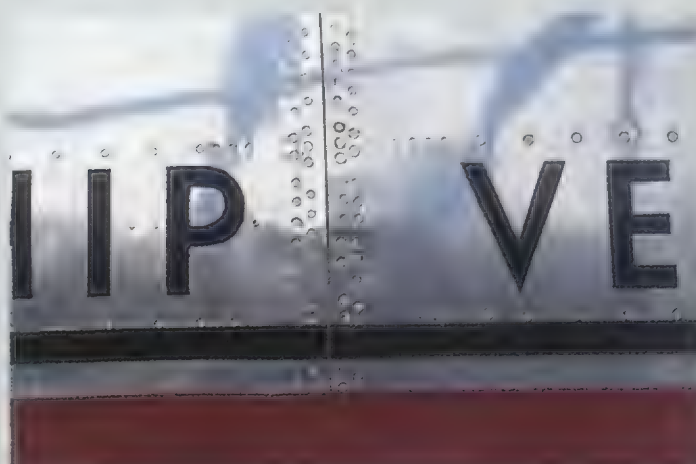
With the big gun pointed skyward, the new riveter inadvertently puts his thumb on the trigger and fires the unrestrained heavy rivet set in an arc over the blast fence and into the North American Aviation parking lot. After a half-hearted attempt to crawl up the greasy fence to observe where the rivet set has landed (and considering that there has been no sound of a shattering windshield), the riveter gives up, slides back down, and trots off to fetch another rivet set.

Upon his return the riveting commences and seems to go smoothly. A few dozen rivets are driven. The 4X gun is loud and deliberate in its staccato tempo: *BAM BAM BAM BAM BAM.*

Then I hear the unwelcome signal from the bucking bar: *THUMP THUMP THUMP.* The shooter sucks air through his teeth, picks up his pneumatic drill motor, and drills out the rivet. A series of incoherent *thumps* emanates from within the wing. The shooter wearily climbs down and approaches the bucker's protruding feet. After a lengthy shouting match, it is evident that the shooter has botched the drilling operation. He has elongated the rivet hole. It is no longer round but egg-shaped.

There is little likelihood of setting a round-shanked rivet into an oval hole. It will distort off-center, or "clinch." And rivet manufacturers do not make oval-shanked rivets. The hole will have to be drilled to accommodate the next size. This restores the desired roundness, but it also enlarges the hole.

As I expect, after the riveter enlarges the hole he surreptitiously reaches into his breast pocket. I know he is drawing from a small supply of "special" rivets. These have shanks of larger diameter to fill oversize holes but heads of smaller rivets. When one of these rivets is installed it appears that all the rivets in a given section are of the same size.



These rivets have unique names. At Douglas they were called Lockheed rivets. Years later, when I worked for Lockheed, I found that workers there called them Douglas rivets. I imagine that at North American Aviation they called them Grumman rivets.

The pair that replaced the original riveting team installed the wing skin without further difficulty, resorting to only three more Lockheed rivets in the process. Meanwhile, the original pair had a heart-to-heart talk in the smoking area. The bucker insisted that he be the shooter on the next job. The shooter was having none of this. "In this world, my friend," he informed his ex-partner, "the population consists of shooters and buckers. There is nothing in between. You're either a shooter or a bucker and nothing can ever change that. And buddy, you're a bucker." Speechless in the face of this frank assessment, the bucker, toting his canvas bag full of steel bars, walked off dejectedly, ending his riveting performance in this theater of the absurd.

A Guide to NASA

Profiles of all the NASA centers, including local maps and visitor information

AIR&SPACE

All photographs courtesy of NASA except where indicated.

THE DOORS ARE OPEN

The National Aeronautics and Space Administration belongs to all of us. The doors are open to everyone at NASA centers nationwide so that visitors can view firsthand the work of the nation's lead agency in the field of aerospace research.

NASA was formed from parts of the National Advisory Committee for Aeronautics (the NACA) when President Dwight D. Eisenhower signed the National Aeronautics and Space Act of 1958 into law. NASA became the first civilian U.S. aerospace agency and was charged with managing research in aeronautics, astronautics, space sciences, and exploration.

At almost every NASA center you can see and sometimes touch real examples of high-performance aircraft and spacecraft and learn about the numerous realms of science in which NASA conducts its research. Most centers provide special facilities for visitors. There you can become acquainted with the history and tradition of aviation and spaceflight in the United States and familiarize yourself with NASA's many activities. Museums, theaters, tours, and gift shops reflect each center's missions and the focus of its research.

Individuals, families, and groups are welcome, and arrangements can be made for group tours. Admission to the centers is free, there are fewer restrictions than you might think (in most areas, cameras are welcome), and the NASA staff is friendly and helpful.

To help you plan your visit, this pullout guide provides descriptions of every NASA center, with particular emphasis on information for visitors.

Dryden's veteran B-52 is still at work, here carrying the new Pegasus air-launched booster during a high-speed taxi test.

HUGH L. DRYDEN FLIGHT RESEARCH FACILITY

Public Affairs Tour Office
NASA Ames-Dryden
Post Office Box 273
Edwards, CA 93523

Activities: Flight research, reentry heating and high-temperature effects, flight instrumentation, flow visualization, remotely piloted vehicles.

Missions/Vehicles: Space shuttle landings and processing, X-29, F/A-18 high-angle-of-attack tests, Pegasus air-launched booster. Soon: X-30 aerospace plane.

Milestones: Site established at Muroc Dry Lake, 1946. World's first supersonic flight, October 1947. M-2 lifting body, 1963. X-15 achieved Mach 6+, 1961. Merged with Ames Moffett, 1981.

Visitor Center	**(805) 258-3460**

7:45 a.m. to 3:45 p.m. weekdays except Federal holidays. Tours twice daily (10:15 and 1:15) except weekends and holidays. Museum and parking free. Gift shop. Flight test film, "Reaching for Tomorrow." 90-minute tour of hangars includes X-29, SR-71. Reservations for groups of 10 or more.

Important: Be prepared to present personal ID, vehicle registration, proof of insurance.

directions: California 14 to Rosamond Blvd. exit, follow signs.

JOHN F. KENNEDY SPACE CENTER

Spaceport USA
Visitor Center-TWRS
Kennedy Space Center, FL 32899

Activities: Assembly, checkout, and launch of space shuttle vehicles and their payloads, landing operations and turnaround of orbiters, preparation and launch of unmanned vehicles.

Missions: Manned and unmanned spaceflight to Earth orbit and beyond. All space shuttle missions, many expendable-launch-vehicle missions. Supports spacecraft requirements of other NASA centers, commercial and non-military government agencies.

Milestones: Construction of spaceport for Apollo missions, early 1960s. Apollo launches, 1969 to 1972. Space shuttle operations, 1981 to present.

Visitor Center "Spaceport USA" (407) 452-2121

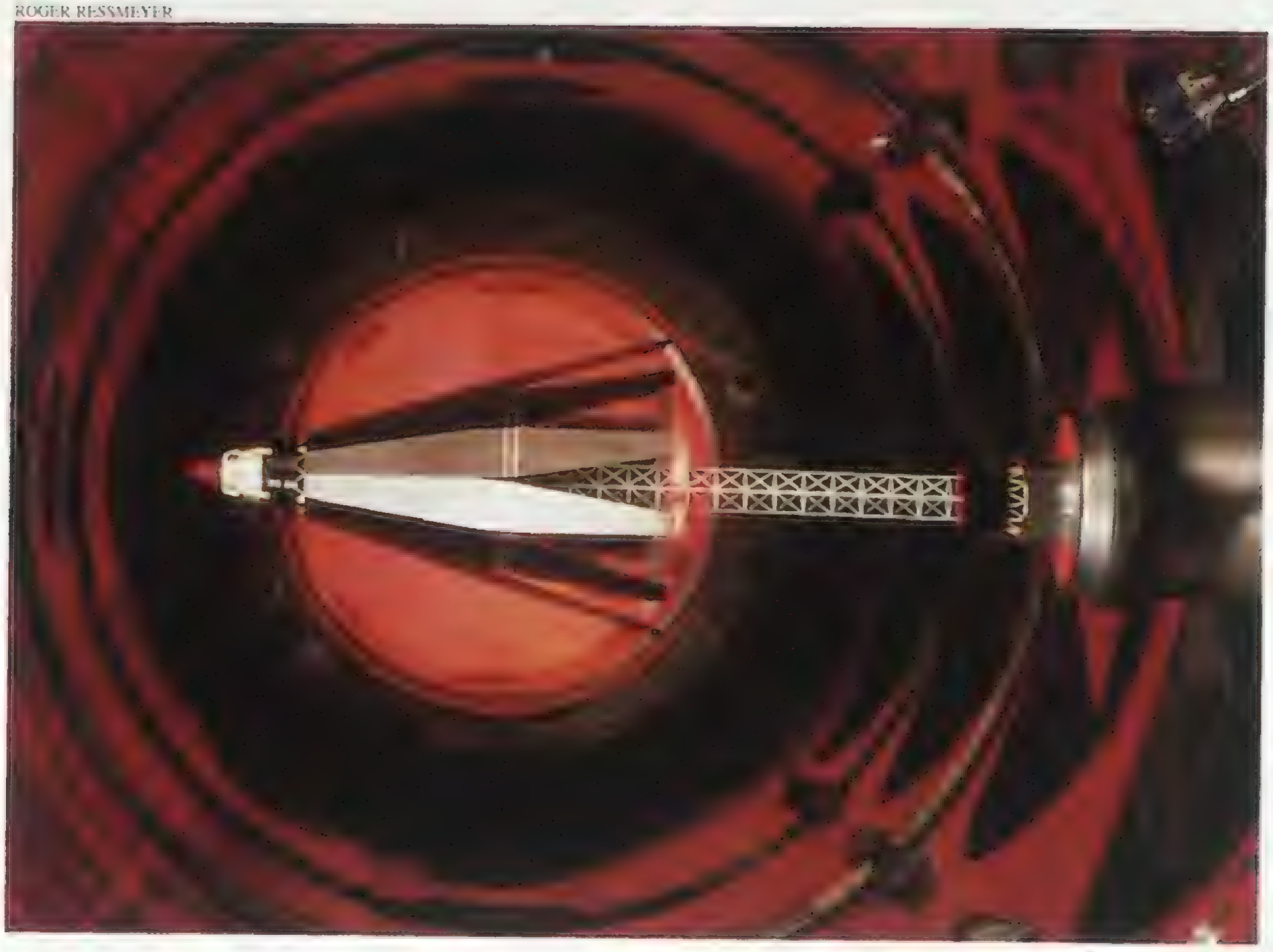
Operated privately under concession agreement with NASA.

9 a.m. to dark, daily except Christmas. Admission free. Cafeterias, snack bars, gift shop. Bus tour (about two hours): adults, $6; children 3 to 11, $3. Blue Tour: Mercury/Gemini blockhouses, launch pads, and mission control. Red Tour: Apollo and space shuttle hardware. IMAX Theater: adult, $2.75; children 3 to 11, $1.75. Galaxy Center houses IMAX, displays, art gallery. Rocket Garden exhibits Apollo booster, launch vehicles. Gallery of Space Flight has space vehicles, spacesuits, moonrocks. Spaceport Central has Fish and Wildlife exhibit. "Satellites and You." Make reservations to visit Exploration Station and Educators Resources Lab, education centers for students and teachers. Wildlife refuge on adjacent lands. About 50 miles from Orlando.

directions: US 1 south from Titusville, follow signs to "Spaceport USA."

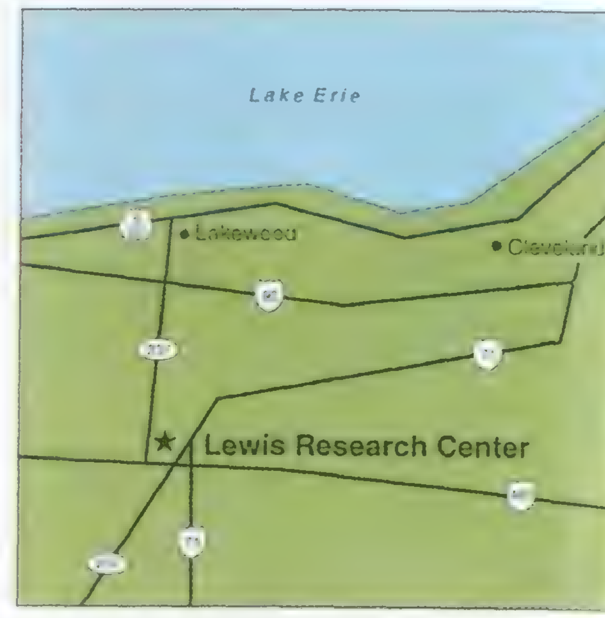
Although Kennedy has its own shuttle runway, most space shuttle missions end with a landing at Dryden, where the orbiter is processed for a piggyback return flight on its modified Boeing 747 carrier aircraft (above). Kennedy has the facilities to mate the orbiter with a new external tank and refurbished solid rocket boosters. After the vehicle is completely assembled, it begins the long, slow trip to the launch pad on a huge tracked crawler (left).

ROGER RESSMEYER



Lewis' prototype nuclear power plant would power ion drives in space.

Visitor Center (216) 433-2001 or -2002
9 a.m. to 4 p.m. weekdays, 10 a.m. to 3 p.m. Saturday and holidays, 1 p.m. to 5 p.m. Sunday. Closed Easter, Thanksgiving, December 24-25, December 31, and January 1. Free admission, eight exhibit galleries. Groups from 20 to 150 reserve at least three weeks in advance for tours, lectures, and programs.
directions: I-480 to exit 9, right on Brookpark Road, follow signs.



LEWIS RESEARCH CENTER

NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135

Activities: Aerospace propulsion including turbines and rockets, space power, satellite communications, research in flight efficiency, noise abatement, safety, reliability, space station, microgravity research.

Facilities: Wind tunnels, engine test cells, rocket test stands, zero-G drop tower, space environment tanks.

Milestones: Established under NACA, 1941, to develop advanced jet propulsion aircraft engines. World War II high-altitude engine research, 1942-45. Jet engine research (compressors, turbine cooling, afterburning), 1945-47. Emission, noise research, 1958-66. Advanced turboprops, 1989.

GEORGE C. MARSHALL SPACE FLIGHT CENTER

NASA Marshall Space Flight Center
Visitor Center
Huntsville, AL 35812

Activities: Heavy-lift vehicle development, shuttle main engines, external tank, and solid rocket boosters, advanced solid rocket motor (ASRM). Combined Release Radiation Effects Satellite (CRESS), Spacelab, Hubble Space Telescope, space station pressurized modules, tethered satellite system, orbital transfer vehicle, inertial upper stage, Gravity Probe-B, Advanced X-Ray Astrophysics Facility (AXAF), space science. Marshall manages the Michoud Assembly Facility, where space shuttle external tanks are made, and Slidell Computer Complex, both in Louisiana.

Missions: Space shuttle, Astro-1, Hubble Space Telescope, Spacelab. Soon: tethered satellite system, AXAF.

JOHN C. STENNIS SPACE CENTER

NASA Stennis Space Center
Public Affairs Office
Stennis Space Center, MS 39529

Activities: Propulsion systems (rockets, turbopumps) testing, shuttle main engine acceptance testing, rocket plume diagnostics (measures rocket engine health), remote sensing and its commercial development, Earth science and environmental research (instrumented Learjet).

Missions/Facilities: Space shuttle, three main engine static test stands, Component Test Facility for testing of turbopumps. Soon: Advanced Solid Rocket Motor test facilities.

Milestones: Site selected for Mississippi Test Facility to perform Saturn V first- and second-stage testing,1961. Later renamed National Space Technology Laboratories, then Stennis. Saturn V static tests begun in 1966. First Apollo moon landing, 1969. First test of shuttle main engine, 1975.

Stennis tests all shuttle main engines before they fly a mission.

Visitor Center	**(601) 688-2370**

9 a.m. to 5 p.m. daily except Christmas. Free admission, tours, films, videos, demonstrations, exhibits. Picnic area, restaurant, gift shop. Cameras allowed at Visitor Center and on tours. Special rules for pets. Group presentations by reservation. Teacher Resource Center (601) 688-3338. Outdoor exhibits: F-1 and J-2 engines, Jupiter-C, space shuttle external tank. Indoors: moonrock, spacesuit, Apollo 4 Command Module.

directions: Follow signs from either I-10 or I-59.

Milestones: Formed July 1960 from part of Army Ballistic Missile Agency. Saturn booster, Lunar Rover, 1960s. Skylab development and onboard experiments, 1973-74. High Energy (X-rays and cosmic rays) Astronomy Observatory series, late '70s.

Visitor Center	**(800) 633-7280**

Located in the Alabama Space and Rocket Center, a state museum.

9 a.m. to 6 p.m. daily September through May except Christmas. 8 a.m. to 6 p.m. in summer. Free admission to Marshall exhibit in lobby of Center. Admission to Museum, bus tour, and Spacedome theater (Omnimax), $11.95 for adults, $7.95 for children 3 to 12 and seniors, children under 3 free. Adults, single event, $6.95. Group discounts. Rocket Park with simulators. Historic Redstone launch stand, observation bunkers. Spacecraft, from Mercury to full-scale model of shuttle. Neutral Buoyancy Simulator. Space station lab and living quarters mockups. Adjacent to U.S. Space Camp and Space Academy.

directions: Follow signs from I-65.

Marshall researchers test new main engine designs (far left). Space station living space and environmental control systems (right) are developed here.

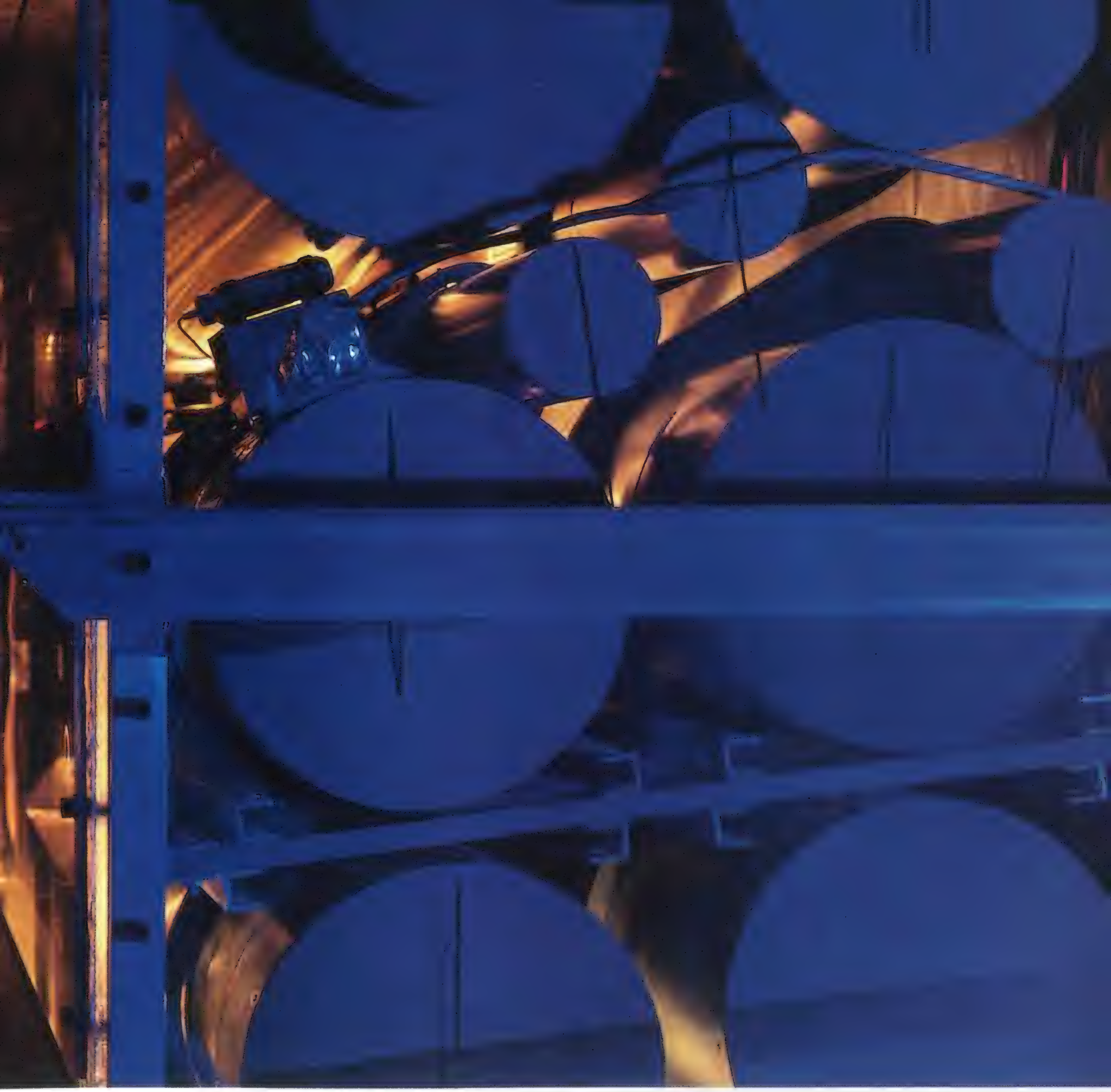
"Before humans become long-range spacefarers, we must design our spacecraft to provide conditions necessary for human life on earth. That includes a breathable atmosphere, agreeable temperatures, water, and three square meals a day.

"Boeing is working with the NASA Marshall Space Flight Center to develop Environmental Control and Life Support Systems for spacecraft. In addition to this contracted work, Boeing has invested its own funds to speed progress.

"The task of my group is to design systems to maintain a suitable atmosphere for astronauts and air cooling for machinery (avionics air), plus automatic fire detection and suppression for both.

"The first use for this technology is Space Station Freedom.

"The avionics air will be very dry and isolated from the air the astronauts breathe. This is because dry air requires less energy to cool, and power



is a premium in space.

"The air people breathe will have about 50% humidity, and will recycle continuously. The system will filter out dust and other particles automatically, add oxygen, adjust gas mixture and temperature.

"The technical challenge is great, but if we all work together, we can make the atmosphere aboard the spacecraft what you'd expect on a typical spring morning: clean, fresh air."

Tamra Ozbolt
Mechanical Design Engineer
Environmental Control and
Life Support Systems
Boeing Defense & Space Group

WE'RE WITH YOU

Boeing has been a partner in America's space programs for more than 30 years.

BOEING

ROGER RESSMEYER

Ames' 40- by 80-foot tunnel, the world's largest, handles full-scale aircraft.

Visitor Center	(415) 604-6497
9 a.m. to 4:30 p.m. weekdays except holidays. Admission, tours, and parking free. Gift shop, 9 a.m. to 3:30 p.m. weekdays. Two-hour group walking tours twice daily, age 9 and over, by reservation (plan several months in advance) weekdays. Tours vary but can include wind tunnels, research aircraft, centrifuge, flight operations. Cameras permitted.	
Important: Tours cancelled in event of rain.	
directions: Highway 101 to Moffett Field exit, turn left in front of Moffett main gate, follow signs.	

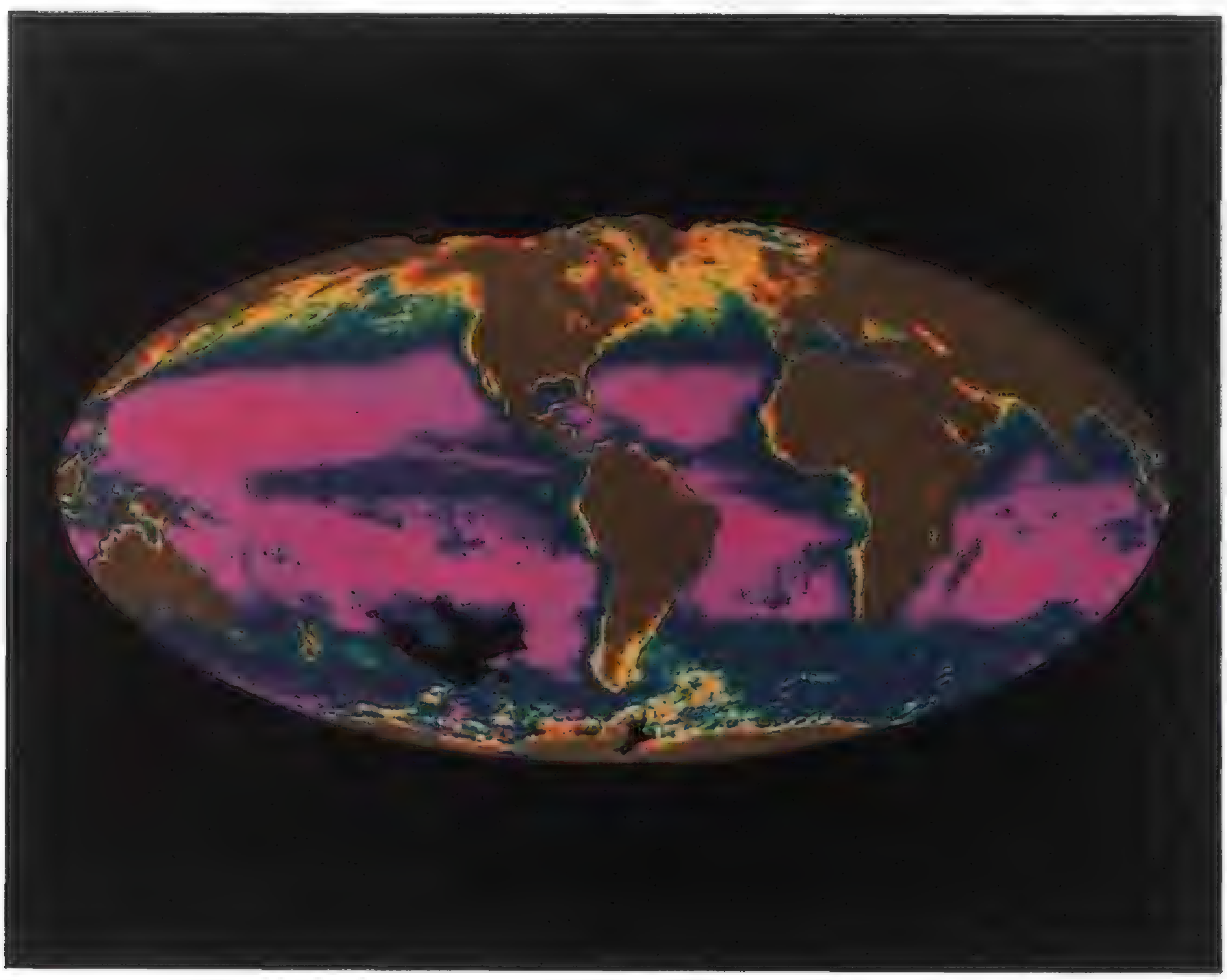
AMES RESEARCH CENTER/MOFFETT

NASA Ames Research Center
Mail Stop TO-27
Moffett Field, CA 94035

Activities: Computational fluid dynamics (CFD) and "supercomputers," wind tunnels, simulation, rotary wings, powered lift, human factors, life sciences, deep-space probes, reentry techniques, thermal protection systems, Search for Extraterrestrial Intelligence (SETI), spacesuit development, infrared astronomy, Earth environment.

Missions: Kuiper Airborne Observatory, Spacelab Life Science Payloads, IRAS, Galileo.

Milestones: Second NACA center, established 1939. World's largest wind tunnel, 40 by 80 feet, opened 1944. Simulator development 1956. Pioneer series of probes, launched 1965-78 (still active). Life science research began in 1961. Hypervelocity Free Flight Tunnel attains flow of 34,000 mph, 1965. CFD branch created, 1970.



GODDARD SPACE FLIGHT CENTER

Visitor Center
NASA Goddard Space Flight Center
Greenbelt, MD 20771

Activities: Communications, climatology, Earth sciences, ultraviolet and infrared astronomy, solar physics, high-energy astrophysics, Delta launch vehicle, space station.

Missions/Spacecraft: Only NASA facility with all the necessary resources (with its Wallops launch site) to design, build, launch, control, and process data for a space science mission. Suborbital vehicles (sounding rockets, upper-atmosphere balloons, aircraft), Cosmic Background Explorer (COBE), Hubble Space Telescope, Tracking and Data Relay Satellite System (TDRSS). Soon: Gamma Ray Observatory (GRO), Upper Atmosphere Research Satellite (UARS).

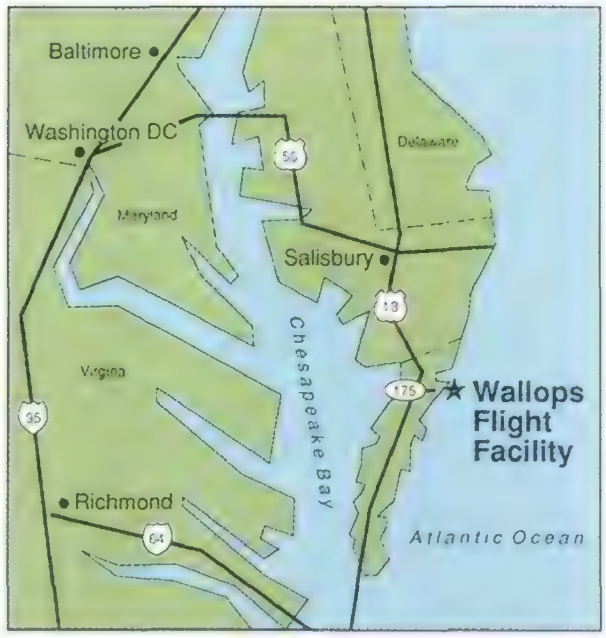
WALLOPS FLIGHT FACILITY
(part of Goddard Space Flight Center)

NASA Visitor Center
GSFC Wallops Flight Facility
Wallops Island, VA 23337

Activities: NASA sounding rocket program for (suborbital) aeronautical and space research, scientific balloon program at various sites around the world, launch range operation, mobile launch, tracking, data acquisition systems in support of other agencies, aeronautical research including airport terminal area research for airline navigation systems, runway traction measurement and research, water ingestion, noise abatement, Earth and atmospheric sciences, sensor aircraft (P-3 Orion), satellite navigation.

Missions: Approximately 35 sounding rocket launches, 100 other rockets of various sizes, 35 balloon launchings annually. Remote sensing aircraft. Since 1961, 21 satellites launched from Wallops.

Milestones: NACA develops site, 1945. Transonic experiments, 1940s-'50s. First satellite launched into orbit by a solid-fuel rocket: Explorer IX, 1961.



Visitor Center	**(804) 824-1344**

10 a.m. to 4 p.m. Thursday to Monday, daily from late June to early September. Closed holidays except Memorial Day, Independence Day, Labor Day. Model rocket launches first Saturday of each month, also third Saturdays in summer. Free admission, parking, exhibits, films, videos, tours in winter months. Picnic area, vending machines, gift shop. Special group programs by advance reservation. Moonrock, spacesuit, full-scale sounding rocket models. Wildlife refuge in adjoining marshlands.

directions: Follow signs from Va. Route 175.

Milestones: Established 1959 as first space exploration laboratory. Assigned primary responsibility for communication and control of space missions.

Visitor Center	**(301) 286-8981**

10 a.m. to 4 p.m. Wednesday to Sunday except Thanksgiving, Christmas, and New Year's Day. Free admission, parking, picnic area, and gift shop. Call three weeks in advance for reservations for tour groups of 20 or more. Models of rockets and spacecraft, mockup of Gemini, "fly" the gyro-chair and manned maneuvering unit, outdoor rocket park, eight-screen theater. First and third Sundays of each month: model rocket launches. Second Sunday: films. Fourth Sunday: hear NASA officials speak. All events begin 1 p.m.

directions: from Washington, north on Baltimore-Washington Pkwy. to Route 193 East, two miles, pass main entrance, left on Soil Conservation Rd., entrance on left. From Baltimore: exit B-W Parkway at Beltsville Agricultural Research Center, follow signs.

Images of Earth composed of data from an array of sensors in orbit—in this case ocean color imagery from Nimbus-7—can portray the entire globe (far left). Wallops' tracking antennas at Woomera, Australia, provide a vital link in relaying sounding data to be stored for later analysis (above).

JET PROPULSION LABORATORY

4800 Oak Grove Drive
Pasadena, CA 91109

Visitor Center	(818) 354-8593
10 a.m. to 3 p.m. weekdays by appointment only; **no daily public access.** Explorer 1, Viking, Mariner, Surveyor.	

Activities: Operated by California Institute of Technology under contract, JPL studies the solar system and conducts interplanetary exploration with unmanned spacecraft. Controls worldwide Deep Space Network to track and communicate with spacecraft.

Milestones: Moon surveys, 1960s. Viking Mars landers, 1976. Voyagers launched, 1977.

ROGER RESSMEYER

Planetary rovers like this prototype equipped with artificial intelligence could precede humans to Mars.

LANGLEY RESEARCH CENTER

NASA Langley Research Center
Visitor Center, Mail Stop 480
Hampton, VA 23665

Activities: Aeronautical research (60%), space science (40%). More than 40 wind tunnels, research in flight efficiency, safety, materials, noise reduction, structures, flight controls, computers, electronics, atmospheric sciences, flight management, space shuttle thermal protection system, National Aero-Space Plane (NASP), space transportation systems, lasers, space station, Earth Observation System.

Missions/Vehicles: Balloons, test aircraft from light airplanes through airliners, navigation testbeds, operations testing, Mission to Planet Earth.

Milestones: First U.S. aeronautical research laboratory, established 1917 under the NACA. First wind tunnel, 1920. Mercury astronaut training, 1958. Apollo lunar lander training flights, 1967.

Vanes at one corner of Langley's 16-foot transonic tunnel enable high-speed air to make the turn. There are more than 40 wind tunnels here dedicated to aeronautics, which constitutes 60 percent of Langley's research. The center devotes the balance of its attention to space science.

Visitor Center	(804) 864-6000
8:30 a.m. to 4:30 p.m. except Sunday 12 p.m. to 4:30 p.m. Closed Easter, Thanksgiving, Christmas, New Year's Day. Free admission and films, picnic area, gift shop, more than 65 exhibits including Apollo Command Module. Reservations required for guided tours and education programs. **Opening 1992:** The Virginia Air & Space Center, a new museum/theater with computerized interactive displays.	
directions: I-64 westbound or eastbound, take exit 63 to Hampton Roads Parkway, follow signs via Magruder Blvd.	

Building 30 houses the Mission Control Center, where flight controllers monitor every aspect of a space shuttle mission. Controllers watch their video monitors as the crew of STS-41 releases the Ulysses spacecraft on its mission to study the sun (top). Soon, the Lunar Lander trainer (left) will move to a simulated lunar landscape at a new visitor center.

LYNDON B. JOHNSON SPACE CENTER

NASA Johnson Space Center
Public Services Branch, AP4
Houston, TX 77058

Activities: Manned spaceflight mission planning, management, and control; space medicine; space station, propulsion, and materials testing (White Sands); astronaut selection and training; shuttle simulation; Weightless Environment Training Facility, zero-G simulation flights (KC-135); Earth and planetary sciences; life sciences; robotics; electronics development and testing. JSC directs operations at White Sands Test Facility, Las Cruces, New Mexico.

Missions/Spacecraft: All manned missions from Gemini to space shuttle.

Milestones: Opened at Clear Lake site, 1963. Renamed for President Lyndon B. Johnson, 1973. Apollo missions, 1969 to 1972. Apollo-Soyuz linkup in space, 1975. First space shuttle mission, 1981. First shuttle satellite retrieval and return, November 1984.

Visitor Center (713) 483-4321

9 a.m. to 4 p.m. daily except Christmas.

Building 2—films, displays of spacesuits, moonrocks, spacecraft

Building 3—cafeteria and gift shop

Building 9A—space shuttle mockup, astronaut orbiter training

Building 30—Mission Control Center, get free ticket at Building 2.

Building 31A—Lunar Sample Facility, moonrocks, lunar lab, and tools

Rocket Park—Saturn V

Follow green signs for self-guided tour. No reservations required. Free parking in designated weekday or weekend/holiday lots. For walking tour through the center, plan on three hours. Tickets required for Mission Control. No pets.

Opening 1991: Space Center Houston, a Disney-designed visitor facility operated by Manned Space Flight Education Foundation.

directions: I-45 south to NASA/Alvin exit, east 3 miles on NASA Road 1, turn in at visitor entrance on left.

by Andrew Chaikin

THE CASE FOR LIFE ON MARS

JPL

A minor change in wording—that's all Gilbert Levin wants. A plaque beside the National Air and Space Museum's replica of the instrument-laden Viking landers says that when the probes touched down on Mars in 1976, they found no evidence of life. What bothers Levin is the *no.* Nearly 15 years after the Viking scientists returned their verdict, he is the lone dissenter among them. For the others, the Viking results are history; for him the debate is very much alive. Where the subject of life on Mars is concerned, Gil Levin just isn't ready to take no for an answer.

RICHARD NOWITZ

LEVIN:
"He said, 'You've disgraced me and you've disgraced science.' I said, 'Will you ever please read the data?' "

On July 20, 1976, the Viking 1 lander alighted on the rock-strewn plains of Mars' *Chryse Planitia,* the Plain of Gold, and began its 90-day mission of taking pictures, analyzing the atmosphere and soil, and looking for signs of microbial life. Tucked inside the lander was a miniature biological laboratory crammed to the hilt with tiny valves, pumps, ovens, and test chambers. The package was so complex that even after years of development it wasn't ready until a few months before the two Vikings were launched; there hadn't even been time to test all the instruments as a unit. The biologists who gathered for the mission at NASA's Jet Propulsion Laboratory in Pasadena, California, wondered whether their experiments would work at all.

On July 28, right on schedule, Viking 1 stuck out a mechanical arm, scooped up a small bit of Martian real estate, and fed it into the biology package, where the alien soil was distributed to three different instruments.

Among them was a test known as the labeled-release experiment, which Levin had conceived in the late 1950s, originally to detect unwanted microbes in municipal water supplies. Inside the instrument, a thimbleful of soil was dumped into a test chamber. Then a drop of nutrient solution, a weak broth of simple organic compounds, was added. The ingenious part of the experiment was that the organic molecules in the nutrient were labeled with radioactive carbon. If any Martian organisms were around to drink the nutrient, Levin hoped they would break down the labeled molecules and exhale radioactive carbon dioxide or other carbon-based gases. All that was needed to detect the feasting microbes was a simple radiation counter. Best of all, the machine proved to be extraordinarily sensitive: in tests on Earth it could sniff out as few as 50 living cells.

Early on the evening of July 30 the first word from the labeled-release experiment came down from Mars. Levin remembers that night as if it were yesterday. Nine hours' worth of data reached Levin and his co-experimenter Patricia Straat in the form of a computer printout. When they analyzed the results they were electrified. After the injection of nutrient the radioactivity count had risen above the background "noise" and headed upward. Near the end it was still climbing. Straat said excitedly, "It really looks like life, Gil!"

At first, Levin says, he was skeptical. The curve of activity didn't look right to him; it seemed to rise more steeply than it had in tests on Earth. But Levin nonetheless fully realized the possible significance of the moment, and on that first night, he and Straat signed their data printout. Then, the next day's data included results that exactly matched those of the Earth tests. And 19 days later, when they performed the crucial control run, in which a fresh sample was first heated to 320 degrees Fahrenheit, they felt all but certain of the discovery: the heat destroyed the activity, just as would be expected had there been living organisms in the soil. They had fulfilled the biology team's stated criteria for detecting life on Mars.

Even though these results were repeated several times by both Viking landers, however, Levin never came any closer to tasting triumph than he and Straat had that first night. NASA biologist Harold Klein, who led the Viking biology team, says that if Levin's had been the only experiment on Viking, "I guess the world today would believe there's life on Mars. But that's not the way it worked."

To Caltech biologist Norman Horowitz, another member of the Viking biology team, Levin is just one more in a

long line of scientists who have been seduced by the promise of life on a Mars that never existed—a Mars conjured almost a century ago by a Boston Brahmin named Percival Lowell.

It was Lowell who trained his telescope on the gleaming red world from his Arizona observatory and saw what he thought were canals, the handiwork of a race of thirsty Martians. By the 1950s Lowell had become an embarrassing historical figure that no one mentioned. But somehow, as astronomers probed Mars with more powerful telescopes and better techniques, everything they found seemed to keep his vision of Mars alive (except for the canal-building Martians). One astronomer found the planet's atmospheric pressure to be—by coincidence—precisely the value Lowell had estimated using much cruder resources. Another detected organic molecules in the dark-colored regions astronomers had long suspected would harbor vegetation. By the early 1960s Mars was apparently a world where humble plant life or perhaps even simple animals might exist, and if they weren't canal builders, these Martians were still enough to satisfy a human longing for company.

"It was just *perfect*," Horowitz says today. "Except it was all wrong. It was all delusion."

It turned out that scientists had been unknowingly deceiving themselves for decades. Time and again, competent, even eminent astronomers had reached mistaken conclusions and confirmed one another's work. It was as if old Percival himself had been there whispering to them while Mars gleamed overhead.

Lowell's Mars began to disintegrate in 1963, when astronomers found the atmosphere far less substantial than previously thought, with a surface pressure only a third what Lowell had reported. In 1965 the Mariner 4 probe made its historic flyby of the planet and further shattered the illusion: the average pressure was only 0.6 percent that on Earth. The real Mars seemed extraordinarily hostile to life: a place of frigid cold and deadly solar ultraviolet radiation—and most important, a place where liquid water could not exist. For many scientists, it was a rude awakening from the Lowellian dream.

"I was a victim of it, same as everyone else," says Horowitz. At the time, he was working with Levin on what would become the labeled-release experiment, but when the real Mars emerged, Horowitz withdrew from the collaboration. "That experiment could not *fail* to detect life on the Earth," Horowitz says. "It was very well designed—but not for Mars."

But how do you design an experiment to search, entirely by remote control, for life on another world? The Viking scientists faced an almost impossible challenge: they had to anticipate what Martian life would be like without knowing whether it even existed. To some it seemed an impossible challenge, and in the late 1960s Harold Klein urged NASA not to send life detection experiments to Mars until more was known

Shortly before Viking 2's Mars landing on September 3, 1976, Levin presented his Viking 1 data to a panel of outside scientists. His conclusions, however, were already doubted by others on the biology team.

HANS-PETER BIEMANN

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In the pre-dawn hours of the day after landing, the first image of Viking 2's barren site gradually appeared on a computer screen at JPL.

about the planet. Of course, the chance to answer that timeless question—Are we alone?—was too tempting for NASA and Congress to pass up, even though, in hindsight, the answer was bound to be ambiguous.

By the late 1960s Horowitz himself had embarked upon another experiment for Viking, unable to resist the chance for exploration but pessimistic about the outcome. In his mind the key issue was water. Mars' atmospheric pressure is so low that a bucket of water placed on the surface would spontaneously boil; only frost can exist there. Mars had surely been wet in the distant past, as Mariner had shown in pictures of huge winding channels that resemble dry river valleys, but present-day Mars is bone-dry.

Horowitz grew even more pessimistic when researchers ventured to Antarctica's frigid, windswept dry valleys, the most Mars-like places on Earth, and found spots apparently devoid of even microbes. It is the extreme dryness of these places, Horowitz says, that makes them unable to support life. Even though the ocean is only a mile away and glaciers and ice-covered lakes are nearby, the valleys contain no exposed liquid water. But he adds, "Compared to Mars, they're a paradise." To Horowitz, the message was clear: if such sterile places exist on Earth, don't expect any life on Mars.

On the outside chance that there might be some form of life that didn't depend on liquid water, Horowitz and his co-workers developed an experiment to meet Mars on its own terms. Known as the pyrolytic release experiment, it exposed its samples to nothing but Martian atmospheric gases and a sun lamp; unlike the other two experiments, which searched for signs of animal life, Horowitz's instrument looked for signs of photosynthesis.

When NASA finally selected the three biology experiments for Viking, Horowitz was amazed to learn that in addition to his own, there were two that made use of liquid water: Levin's and an experiment called the gas exchange test, designed by NASA scientist Vance Oyama. Oyama's instrument could either humidify its sample with water vapor or drench it with a strong organic "soup"; Levin's employed a couple of drops of weak nutrient to wet only the center of the sample, producing a gradient of moisture. Because they employed liquid water, Horowitz had no qualms about saying that neither of his colleagues' experiments belonged on the mission, branding them "irrelevant." By the time the Vikings were en route to their rendezvous with the Red Planet, Horowitz was extremely pessimistic, but he was certain of one thing: if there was life on Mars, his was the only biology experiment that would find it.

It was no surprise that the biology team was not a harmonious group. From the early stages of the Viking project, their meetings were so stormy that NASA called upon Klein to serve, he says, as "something of a rabbi to keep peace in the family. I knew that my job fundamentally was to keep those guys from annihilating each other."

From the beginning, Levin struggled for acceptance from his teammates. Unlike the others, who held prominent positions at universities and NASA research centers, he was president of a small environmental science corporation. His tall, tanned, smiling presence further set him apart from the other biologists; as one writer who covered the mission observed, "Some of them looked like they'd spent too much time in the lab; Levin looked like he'd been spending too much time on the golf course." But his *bon vivant* appearance was deceiving; Levin was anything but casual about his involvement in the mission. "He stopped his whole life for Vi-

king," says NASA's Gerald Soffen, who served as Viking's project scientist and was close to the biology team. "Of all the scientists on the team, Gil was probably the most devoted. He ate it, drank it, slept it."

Today, Levin is convinced that his background worked against him. Some of the others also recall a certain undercurrent of snobbery, but Horowitz says: "I deny that it was snobbery. It was scientific, not social." Whatever the other scientists thought of Levin—and many respected the ingenuity of his experiment—they never came to accept his claim that his data indicated life.

Had the labeled-release experiment been the first to report from Mars, at least their initial reactions might have been different. But the day before Levin and Straat's first data arrived, Oyama's gas exchange experiment had already given a strange and surprising positive reading. When Oyama's sample was humidified it released a startling burst of oxygen. No one took that reaction for life; it was too much too soon to be the heavy breathing of Martian microbes, and it did not sustain itself. (When the same sample was later drenched with Oyama's organic soup, nothing happened.) But the result seemed to reveal something entirely unexpected and extraordinary about the surface of Mars: it was chemically reactive. Some highly oxidizing substance—perhaps as simple as hydrogen peroxide—was apparently present on Mars, probably formed by the interaction of ultraviolet sunlight with the atmosphere and surface. When the peroxides reacted with the water vapor in Oyama's experiment, oxygen gas was produced. Adding liquid nutrient produced no response, the scientists reasoned, because the first reaction had already used up the peroxides in the sample.

SOFFEN:
"We did more than say we couldn't find life; we said it's probably not there."

The results from Levin's experiment were more confusing. They seemed to be something halfway between biology and chemistry, but the most important fact, to Horowitz and others, was that the activity curve didn't steadily increase until the nutrient was used up; it leveled off after a couple of days. Nor did a second injection of nutrient on the eighth day produce a response. But the peroxide theory seemed to explain the data—the other scientists suspected that oxidants had reacted with one of the compounds in Levin's nutrient.

Finally, two and a half weeks after landing, Horowitz's pyrolytic release experiment sent its first report. By this time Horowitz was certain that chemistry and not biology was the answer to what was happening on Mars, but he also felt confident that because his experiment used no water it would not be affected by any oxidant. If his instrument recorded any activity, he would have to consider life as an explanation. And so Horowitz was stunned when his first data showed a weak but positive response.

"It was amazing. We could hardly believe it," Horowitz recalls. "George Hobby and Jerry Hubbard [Horowitz's collaborators] and I were looking at the data, wondering 'What the devil could they mean; could they mean there's life on Mars?' And we wanted to repeat the experiment immediately." But that was not to be. "We did try to repeat it and never could get that high reading. We decided that our first result was an error of some kind. I still can't explain it." Once again Mars had confounded the biologists with an ambiguity they had never anticipated.

Levin and Straat, meanwhile, were hard at work challenging the peroxide theory. As they saw it, nothing about their results favored chemistry over biology. So what if the response leveled off? Maybe the water in the nutrient was lethal to microbes adapted to bone-dry Mars. When the second squirt of nutrient was added, they were already dead.

By now Viking 2 had touched down on Mars' *Utopia Planitia,* and its first labeled-release data were even more positive than Viking 1's. When it came time for the control run Levin and Straat modified their procedure in an effort to help eliminate the chemical hypothesis. This time they heated the sample to only 122 degrees Fahrenheit, a temperature that chemists agreed was too low to interfere with most chemical reactions but hot enough to kill microbes. These results were negative, suggesting life, but for Levin it was a losing battle: his colleagues still held to the chemical explanation.

The worst blow came when the team's elder statesman, Nobel laureate biologist Joshua Lederberg, pronounced the labeled-release data "trivial." On the biology team, says Soffen, "Lederberg's views were treated like sacred

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words. When he didn't have any interest in Gil's data . . . we didn't think it was life anyway, but that sealed it."

Looking back, Levin is still frustrated by the way his teammates responded. Weren't the experiments designed so that only one would return a positive response? Hadn't he fulfilled the criteria for detecting life? He says the biologists changed the rules on him.

"It's really Mars that changed the rules," Klein says. "We were all starting on the assumption of a Mars that doesn't exist. That's the real problem." None of the biologists had imagined that the real Mars had peroxides. It was the kind of scenario they dreaded.

"All of us feared more than anything else a false positive," Soffen recalls. "We had meetings and meetings about how we'd announce it and who would announce it. No one wanted to say 'We found life' and then say 'Sorry'—the whole credibility of science is shot! So there was a lot of resistance to getting up and saying there was life."

In time, Klein says, the ambiguity of the story drove some reporters to distraction. After Klein gave a talk about the biology results in Washington, D.C., he remembers, TV correspondent Bernard Kalb approached him. "You scientists," said Kalb in frustration. "You guys just can't make up your minds. Why can't you tell us one way or the other: there is or there isn't life on Mars?"

Klein answered simply, "Look, that's life."

Ironically, while Viking's life detection experiments seemed to tell more about Martian chemistry than biology, the most surprising data, and the finding that seemed to decide the biology question, came from an experiment that was never designed to look for life. The instrument, called the gas chromatograph/mass spectrometer, or GCMS, analyzed the soil for organic material rather than living organisms specifically. Everyone had expected that even if the biology experiments found no trace of life on Mars, the GCMS would detect organic molecules—carbon-based compounds that are the building blocks of life as we know it—either produced by the interaction of Mars' atmosphere with ultraviolet sunlight or derived from certain kinds of meteorites that scientists had found to contain organic matter. But to the amazement of everyone, the two GCMS instruments reported not a hint of organic matter.

"That result is the single most important result that Viking got on Mars," says Horowitz. "It shows definitively there can't be life at either landing site."

Not everyone is as emphatic as Horowitz. Patricia Straat says, "It strikes me that Norm won't even allow for the *pos-*

Viking managers evaluated possible sample sites—nicknamed Eeny, Meeny, Miny, and Mo—in areas accessible to the lander.

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sibility that maybe the results mean life on Mars. And I think that's erring in the opposite direction." For most of the Viking biologists, however, the GCMS results were enough to seal the case against life.

But how to reconcile the seemingly conflicting results from the three biology experiments, not to mention the startling lack of organic matter? Klein, the biologist charged with making sense of the entire picture at the end of the mission, says they are all pieces of the same puzzle. If peroxides do exist on Mars, as Oyama's experiment seems to indicate, they would destroy whatever

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"We were all starting on the assumption of a Mars that doesn't exist. That's the real problem."

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organic matter is present, making Mars even more hostile to life than previously thought. At the same time, Klein says, they probably caused the positive response in Levin's experiment. Without Oyama's crucial finding, he adds, "we'd be scratching our collective heads wondering whether maybe we were just unlucky at the two Viking landing sites, and that maybe organic compounds were present on Mars but were simply outside the reach of the two samplers. And we'd be talking about giving Gil Levin a Nobel prize for his discovery of life on Mars."

With such odds stacked against life, the other biologists have chosen to accept the chemical explanation, despite the fact that no one has directly detected oxidants in Martian soil. Instead, the evidence comes from laboratory simulations such as those performed by geochemist Robert Huguenin, now with Aerodyne Incorporated, who says oxidizing agents are constantly forming on Mars from the interaction of surface minerals with atmospheric water vapor. Using these oxidants, Huguenin says he has simulated the results of all three biology experiments.

And so the verdict was in. "It punctured dreams," Soffen says. "We did more than say we couldn't find [life]; we said it's probably not there. No question that it influenced the space program." There had been plans to follow the Vikings with rovers, but they haven't yet materialized. The biologists put the search for life on Mars behind them—except for Gil Levin.

Levin has continued to publish papers defending his results. His main point is that he and Straat reproduced their Mars results with terrestrial organisms. The chemical explanation does not explain the data as well, he says, and it raises some nagging questions: If peroxides are formed by ultraviolet light, why did a sample taken from underneath a rock—which geologists believe shielded the soil from ultraviolet light for 100 million years or more before Viking 2's sampler arm pushed it out of the way—yield a positive response in the labeled-release instrument? Why, on the other hand, did soil kept in a darkened storage container within the lander for two months before it was analyzed—during which time, Levin reasons, any microbes probably died—give no response? To him the chemical explanations require as many contortions as his opponents charge are needed for the life explanation.

Furthermore, Levin says, the very keystone of the biologists' no-life conclusion—the GCMS findings—is in error. Back in his lab after Viking, Levin discovered a report of a pre-mission test in which the GCMS and the labeled-release instrument both analyzed the same soil sample from the Antarctic dry valleys. According to classical methods, the sample was sterile, and indeed, the GCMS detected no organic matter. But the labeled-release instrument found life. And the device, according to Levin, was not malfunctioning: when a control sample was heat-sterilized, the instrument correctly returned a negative finding. In other words, Levin says, the supposedly sterile test sample was alive—but the number of microbes was below the GCMS' level of detection. And that, he says, is just what happened on Mars.

Could those few tiny Antarctic denizens turn the entire case in Levin's favor? Klaus Biemann, the MIT chemist who headed the GCMS team, does not challenge Levin's statement about the Antarctic sample, but he says it doesn't change anything. Biemann reiterates what he said before the Vikings got to Mars: The GCMS was never meant to be a life detection experiment. "It was the biologists who said, before the mis-

sion, that if there are no organics they won't believe the positive responses of their own experiments."

Biemann insists, however, that the GCMS results raise a fundamental problem for Levin. If Martian microbes really did cause the response in the labeled-release instrument, they must have been very few in number or else the GCMS would have detected their remnants. And while that is possible, says Biemann, that scenario—each Martian a lone king of the mountain in its own little sand patch—is difficult for other scientists to accept. "What does Gil think those organisms were doing there," asks Biemann, "just waiting for his experiment? Those are the questions which he as a biologist should ask himself. Not just whether the signal was positive—which is a debatable thing." The bottom line, says Biemann, is that unless biology on Mars is fundamentally different from that on Earth—in which case, all bets are off—any living species must multiply to the point where the GCMS would have detected its accumulated organic debris.

Levin responds, "Isn't that very geocentric in thinking? Who knows what appropriate numbers are? Suppose you had an instrument that detects people. You'd have a hell of a time in the Sahara desert, but there are some."

Portions of the Viking 2 lander dominated the image in Klaus Biemann's hands. Firm evidence of life, however, remained elusive.

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Long after his colleagues have moved on to other things, Levin is still trying to win them over. "Gil is, first and foremost, one of the best salesmen I've ever come across," says Soffen. But he and the other biologists remain unswayed by Levin's best efforts. "The first few times you're patient," Soffen says. "Then you get sick of it. There's nothing new."

Levin hasn't helped his case by venturing into image analysis, an area outside his expertise. In the late 1970s he announced that he had studied some of the rocks in the Viking images and identified greenish spots that seemed to change over time. When he mentioned "lichen" in the same breath, his colleagues rolled their eyes. Even though Levin says he never meant to imply that the spots actually are lichen—he says he simply used lichen as a *model* for one form life on Mars could take—something about his presentation has others jumping to that conclusion, with anything but enthusiasm. Even former coworker Straat says, "I think he's gone too far."

For Viking alumni, July 1986 was a time for looking back, and many were in attendance at a NASA-sponsored conference on Mars at the National Academy of Sciences. In his presentation, Levin told his audience, "It is more probable than not that living organisms were detected in the LR experiment on Mars." To close his talk he showed the pictures of spots on the rocks and again talked about lichen. Horowitz, who had just given his own talk summarizing the case *against* life on Mars, was aghast. When the two men crossed paths at a cocktail reception in the Academy's Great Hall, Levin remembers, sparks flew.

"We practically had a fistfight," Levin recalls. "He said, 'You've disgraced me and you've disgraced science!' I said, 'Will you ever please read the data?' " At the next day's session, Levin adds, Joshua Lederberg—who had called the labeled-release data "trivial" 10 years before—expressed regret that the Viking results had been "misinterpreted" by Levin.

Today, Levin looks a bit haggard, as if

15 years of uphill fighting have taken their toll. When he talks about Viking the ragged edge of frustration creeps into his voice. "They will all say that Levin says there's life on Mars. I have never, ever made that statement. Never. I've been very careful never to make it. I *have* said that this evidence is positive. And I don't think the data got the respect that they warranted."

Surprisingly, some of the most supporting words come from geochemist Huguenin. "It's unfair that people would judge Gil Levin as a loony or something. He's got a very valid point when he says that the results were entirely consistent with the presence of life on the planet. No one can argue with that. Because he's reproduced them.

HOROWITZ:
"It was just *perfect.* Except it was all wrong. It was all delusion."

"But remember," Huguenin adds, "that the rules of the game were that life is an explanation of last resort, because of the significance of the finding. You have to rule out other possibilities first." It is that proposition—that erring on the side of conservatism is an acceptable mode in science—that Levin cannot accept. Indeed, he concludes sadly that his colleagues, in saying the Vikings found no evidence of life, have abandoned the scientific method.

"There isn't a day that goes by that Mars isn't on my mind," Levin says. "I really think about it. Every day. And what is really driving me is, I want to know the answer."

But what would that take? "If there were another Viking tomorrow, most biologists wouldn't be interested," Soffen says. Of those who would try, he cautions, "they'd have the same problems we had."

Klein agrees. "I'm still telling NASA and the Soviets, 'If you want to go back to Mars, don't do any life detection experiments yet." Ironically, as plans for Mars missions are debated, Klein says, geologists and other physical scientists are more avid promoters of life investigations than biologists. "Of course, the reasoning is obvious," Klein says. "They now realize that from a political point of view, in order to sell the mission it would be much more charming to say we're going back there to look for life than to say we're going back to look at rocks." He adds, "In the last six months we on the inside have succeeded in toning down this eagerness to go back to look for extant life." NASA's current plans mention only a quest for fossils or other evidence of past life. Here again, Levin is going against the tide: the thought of returning to Mars without trying to settle the question once and for all is, he says, "insane."

Soffen says the biologists *would* jump at the chance to analyze something Viking could never give them: a scoopful of Mars brought back to Earth. But even that, he adds, might not prove conclusive. The final answer may not come until human beings finally walk in the dust of the Red Planet—in which case, Levin is in for a long wait. For now, life on Mars remains elusive, an explanation of last resort, and the best wording for that sign in the National Air and Space Museum seems to come from Soffen's assessment: "There's only one sane position: that we don't know."

CHAD SLATTERY

Like cheerleaders and marching bands, blimps have become a permanent part of the spectacle we call football.

THE BLIMP

by John Grossmann

Photographs by Chad Slattery

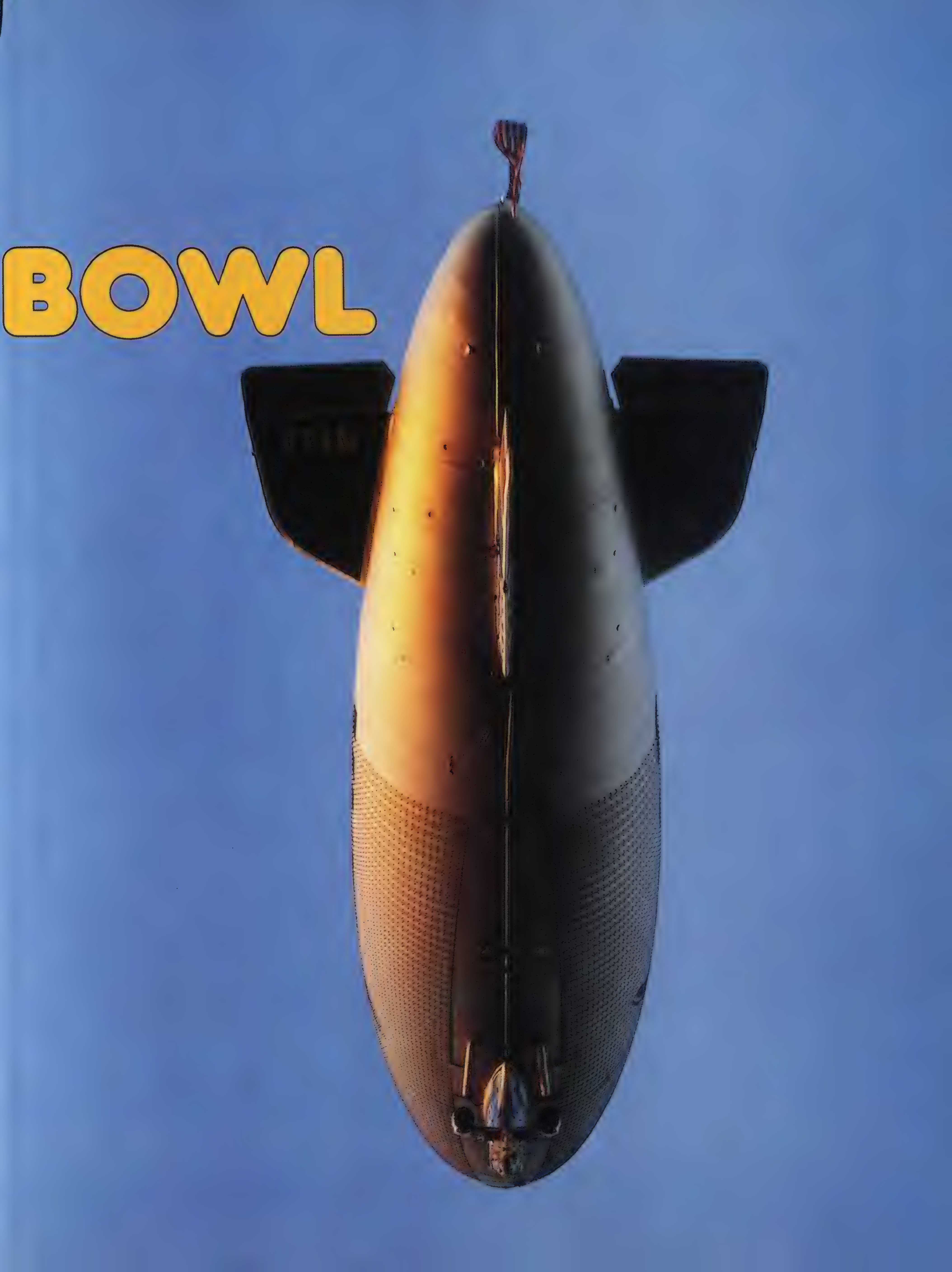
Four hours to kickoff. Some five miles from Spartan Stadium in East Lansing, Michigan, where Michigan State will soon host number-one-ranked Notre Dame, another team goes through its pre-game rituals. On a grassy island near a taxiway at Capital City Airport, a 16-man crew is transforming the Goodyear blimp *America* into an aerial camera platform.

Out of the gondola, or car, come passenger seats, unbolted from the floor. The rug is rolled up and carried away. Off comes a door-size side panel behind the pilot's seat. On board is hoisted some 790 pounds of TV camera gear, monitors, and controls. The most striking piece of equipment is a huge white eyeball, which hangs below the car on a winch. Inside this eyeball is a gyro-stabilized, state-of-the art Ikegami 323P camera with a 44-to-1 zoom lens. Rack to lens, the system costs a cool $350,000. Goodyear has three, one for each of its airships.

Together, those three blimps make up perhaps the hardest working corporate symbol in show biz. The *America,* which winters in Houston, and her sister ships, the *Columbia,* based in Los Angeles, and the newest blimp, the *Spirit of Akron,* based in Pompano Beach, Florida, each fly more than 100,000 miles a year. They fly passengers on half-hour joyrides and cruise with their night signs scrolling messages and graphics Times Square-style. Simply flying from one job to the next, the blimp (it's easier to think of them as a single entity) is at work as a head-turning, traffic-stopping, low-flying billboard. (Goodyear doesn't like to talk costs, but in the early 1980s the company acknowledged an annual operating budget of $2.5 million per airship and pegged the replacement cost for a model GZ-20, *America*'s 192-foot-long, 57.5-foot-high design, at $5.5 million. Both those numbers, clearly, have since risen.) The Goodyear Tire & Rubber Company, which has manufactured more than 300 airships since 1917, likes to call its lighter-than-air trio "Goodwill ambassadors."

The blimp's most visible role is covering sports. Goodyear first assisted network sports coverage in December 1960, flying the airship *Mayflower* over the Orange Bowl Regatta (and apparently not, to the best of anyone's recollection, the Orange Bowl game itself) with a CBS-provided camera crudely mounted on a two-by-ten. By 1970 the blimps' sporting assignments had grown to 20 events; by 1980, 50 events; last year it racked up more than 75. Baseball playoffs, the World Series, key college football matchups and bowl games, "Monday Night Football," the Indy 500, the U.S. Tennis Open, the Kentucky Derby, the Masters golf tournament—

A Goodyear blimp can carry up to six passengers plus a pilot—today it's Tom Matus (left). Blimps are so safe the FAA doesn't even require them to have seat belts.


BOWL

Camera operator Fred Hildenbrand examines one of the three videocam systems Goodyear has for its fleet.

virtually all the big games have a blimp hovering overhead. Viewers have become accustomed to panoramic blimp shots of full stadiums—and a shot or two or three of the blimp itself. Following Goodyear's lead, Metropolitan Life, Sea World, and Fuji have all taken to the sky—and to sports coverage—to increase corporate visibility.

The competition is likely to increase, for Goodyear plans a major cutback in sports coverage for 1991. "In the current economic climate, we need to utilize our blimps more for direct product support, use the pulling power of the blimps to increase the traffic in our stores," says Goodyear spokesman Richard Sailer. "Consequently, we expect to cut back to 25 or 30 events." At each of those events, the role of the blimp will unfold much in the manner of airship *America*'s imminent role above the gridiron today.

As the blimp is readied for the Michigan-Notre Dame game, chief pilot John Moran stands nearby crunching a few numbers in his head, mindful to stay well outside the arc traced in the grass by the single wheel beneath the cabin. *America* is moored to a 33-foot mast that's guy-wired like a big-top tent and erected by the ground crew with old-fashioned circus flair (and modern electric stake drivers). Fastened by its nose only, the airship turns with the wind, and standing just outside the arc its wheel describes puts you in possible contact with the ship's pusher props. Seasoned pilots don't make this mistake. In his blue Goodyear uniform, aviator-style sunglasses, and well-shined black shoes, Moran certainly looks seasoned, though the tiny gold-stud earring adorning his left ear lobe is a surprising touch. He is 46 years old and has been flying Goodyear blimps, including the discontinued overseas cousin, the *Europa,* for more than 20 years.

It's the pilot's job to specify the amount of fuel pumped aboard, taking into account both the amount needed by the twin 210-horsepower engines and the fuel's weight. Moran expects to encounter westerly winds of more than 15 mph and gusts likely to exceed 30 mph. In other words, he's going to burn a lot of fuel, upwards of 10 gallons an hour, most of it to go essentially nowhere.

Finally it's time for takeoff. Once ground crew chief Jonah Carver gives the raised-thumb signal, the half-dozen or so crew members hanging on to the handrail below the gondola simply give the blimp a boost. Then Moran guns the engines. A heavily loaded blimp usually needs the momentum of a rolling takeoff down a runway to get airborne, but today, with takeoff seconds away, a powerful updraft grabs the ship and *America* angles sharply toward the clouds.

Moran levels off at the standard cruising altitude of about 1,000 feet. To the right of his seat is the control for the ship's elevator, looking enough like the

A View From the Blimp

Over the years, the views from the Goodyear blimp have been varied. Senior pilot Mark Kynett once saw a fishing boat releasing a huge slick of oil into a river and wished there were some way to report it. Fellow pilot Dan McDuff has called in a fire. John Moran has followed the path of a tornado that had struck the day before. And flying in Italy early one morning, he happened upon a missing aircraft in a field, its occupants unhurt and waiting on the wing for somebody to spot them. Less happily, flying up the East coast several years ago, he spotted a body floating in the ocean. "The beaches were empty," he recalls. "But I saw some construction workers and flew over right beside the house they were working on, idled the engines, and yelled to them. One of the guys hopped into the water. I directed him to the body and he pulled it in. Some weeks later a letter finally made it to me. It was from a couple thanking me for finding their son's body. He'd been missing for five days." And who can forget the historic, unsettling views from the *Columbia* two World Series ago, when, just before the start of game three at Candlestick Park in San Francisco, the earth began to rumble. The blimp swung away from the ballpark and provided the nation with the first views of the crippled Bay Bridge and the inferno growing in the city's Marina district.

wheel on a wheelchair that more than one Goodyear blimp passenger over the years has inquired about the pilot's disability. To Moran's left are the engine controls. Still, the busiest parts of a blimp pilot are his legs. Moran steers the *America* with his feet, which rest (in a manner of speaking only) on metal pedals angled a couple of inches off the floor. With the blimp constantly buffeted by wind and thermals, simply holding a course or staying put requires near constant pedaling. Essentially, Moran works like an airborne unicyclist.

"No, I've never strapped on a pedometer," Moran says, suddenly yanking on the wheel with both hands and pointing the nose of the ship steeply down in response to a strong updraft. He smiles. "It's going to be a long day." The winds are now gusting to 35 mph, and Moran's tight-fitting communications headset only slightly muffles the loud drone of the engines.

Behind Moran, cameraman Glenn Hampton sits on a swivel chair, warming up his skills on the brief flight to the Michigan State campus by following a red van on a road far below. Hampton faces three monitors—upper left, the view from the blimp camera, currently the red van motionless at a stoplight; upper right, a wave-form monitor that helps him maintain proper contrast in his picture; and below this, a small screen that provides, *sans* sound, the picture seen in millions of living rooms—right now, second-half action of the ABC telecast of the UCLA-University of Michigan game. When it ends, ABC will come live to East Lansing. With a glance at this monitor, Hampton will know when his shots are on the air.

The Gyrocam 360 system is a big step up from a camera mounted on a plank—the rig used by the Mayflower *to cover the Orange Bowl Regatta in 1960. Inside a blimp, cameraman Glenn Hampton uses joysticks to line up the shots television viewers have come to expect.*

He operates both camera and lens remotely, arcade style, with hand controls mounted on a small panel just above lap height. His right hand, on a joystick, controls pan and vertical; left hand, zoom and focus. A couple of turns of his left hand and Hampton zooms in on the van close enough to all but read its license plate. He can, he says, actually follow a baseball leaving a bat, especially a grounder.

Out the gondola windows now the view is festive. The band rehearses its halftime marches on a grassy practice field. Like a sunburst, motor homes and station wagons radiate in orderly rows from the stadium—tailgaters' heaven. The first specks of color appear in the stands as impatient ticket holders claim their seats.

Moran's headset, as well as Hampton's, carries the voice of Goodyear's manager of films and broadcasts, Mickey Wittman, who's already in the


GOODYEAR
GOODYEAR

ABC television truck, positioned at the elbow of director Larry Kamm. Wittman acts as liaison to the networks, helping them achieve the coverage they want from the blimp and, conversely, sometimes trying to "sell" them, in TV jargon, on airing specific shots from the blimp. Look for the dish, Wittman reminds Moran. He means the microwave receiving dish responsible for capturing the camera signal beamed down from the blimp. This dish, about the size of a Flying Saucer sled, was positioned yesterday atop a flat-roofed athletic building near the stadium and adjacent to the broadcast truck, to which it is wired. It's mounted on a tripod and must be constantly swiveled by a Goodyear technician to follow the ship's movements in order to maintain peak reception.

The shot from the blimp, already appearing on one of the many monitors in the broadcast truck, is but one of 10 live views at Kamm's disposal. ABC has seven fixed cameras and two hand-held cameras at the ready; six of them, as well as the blimp camera, are potential replay sources.

On the dashboard Moran has placed a list of six "beauty shots" the blimp may be asked to cover during the telecast. The list includes the state capitol building in Lansing and various campus landmarks and new buildings—the latter apparently selected by ABC as much for alumni appeal as for architecture.

"Okay blimp, give me Breslin Student Center," coaches Wittman.

Moran turns the blimp and Hampton turns the camera, searching out one of the buildings he and Moran had pinpointed yesterday from on high with the help of a campus map. Moran keeps tabs on the blimp camera by glancing toward the floor to his right, where two monitors are held together and fast with duct tape. The left screen shows the blimp shot. The right screen shows the ABC telecast. Moran asks Wittman to relay a message to the director: "Tell him when he wants a shot he's got to give me some time because of this wind."

Not only does a Goodyear pilot use both hands and both feet, but with his

Looking like part of Macy's Thanksgiving parade, Columbia*'s ground crew prepare for a launch.*

The Pilot's Perspective

"I don't think most fixed-wing pilots are aware of how serious a flying job it is," John Moran says of his piloting duties. "You have to develop a seat-of-the-pants feel for the airship. An airplane bounces around in turbulence, but you know what it's going to do. You don't know what an airship is going to do. Because it's so big and so slow, you can have two different air currents affect two parts of the ship simultaneously, maybe an updraft on the nose and a downdraft on the tail. You really notice this on especially sunny days when you come in to land, moving over grass and plowed fields to paved areas."

headset on during a telecast, he's got voices coming in both ears—lots of voices. In Moran's left ear: Wittman and director Kamm from the broadcast truck; also cameraman Hampton. Right ear: ground crew technician at the dish, air traffic control, and flight service. On occasion: a two-ear, six-voice circus.

"Hello blimp, it's the truck," Wittman says closer to kickoff. "Just like that. That's a perfect location for 3:30."

From the truck comes the voice of Kamm, commanding his small army. The broadcast has begun. "Roll to 21. Twenty seconds to you, Ralph. Stay wide on the blimp, please . . . . Ready to dissolve to the blimp . . . ."

Moran's two screens bear a single image. The blimp camera has the nation's attention. Hampton's holding a wide shot of the jam-packed stadium framed by some of the campus.

"Push in," commands Kamm.

Hampton zooms in tighter.

"All the way in . . . . Dissolve to camera two."

Soon, announcers Keith Jackson and former Miami Dolphins quarterback Bob Griese appear on the screen, setting the stage for the day's game. Blimp shot number two is a tight stadium view that widens to show the armada of parked cars. Kamm cuts to a tailgate party, then to commercial.

Like all directors, Kamm is happy to have a blimp at his disposal. In fact, he'd like to have a blimp over every outdoor sports event he televises. "If the blimp can help us provide the viewer with a sense of place and a sense of spectacle, it's done its job," he says. He does not like to use the blimp for coverage of the action, with the exception of auto races, where the blimp camera can follow the cars around the track, providing both a sense of speed and, in panning back, say, from a pair of bumper-to-bumper leaders, a good perspective on how far ahead they are. "To cover a play from scrimmage from the blimp is disorienting and unfair to the viewer," Kamm says. "It's a device and a gimmick, and it can wind up hurting your telecast if not used properly. You try and weave it into the pattern. Make it part of the whole cloth."

Blimp shot three, coming in from another commercial, provides the first on-air mention of the blimp. Says announcer Jackson: "They're just certain they're going to have a new attendance record today at Spartan Stadium. There will be over 80,000 people. As we look down on it from the Goodyear blimp."

A blimp's rubber-coated polyester envelope is filled with helium—not the hydrogen of Hindenburg *infamy.*

GOODYEAR
COLUMBIA
N10A
BRUINS
UCLA
Rose Bowl

No football game is complete without a blimp over the stadium. Here, Columbia *surveys the Rose Bowl.*

Moran, right hand off the wheel for a moment, flexes his fingers to release some of the tension starting to build in his arm. He admits the pain typically shoots well up the forearm long before a day's coverage ends.

Late in the first quarter Kamm says, "I'll do a blimp pop after the exchange [of possession of the ball]." This rather interesting choice of words turns out to refer to a visual of the blimp itself. It appears with 26 seconds left on the clock, after Kamm has asked his cameramen, "Okay, who can see the blimp?" and first established a smooth bridge by cutting to another shot from the blimp. "The Goodyear blimp *America* out of Houston, Texas, is bringing you that picture," says Jackson, as the blimp appears against the darkening sky. "The pilot is Captain John Moran of Spring, Texas. Hey John. Haven't seen John in a couple of years."

Although the Goodyear crews do enjoy friendly relations with the television folks, it's not simply friendship that begets such warm mentions and blimp pops. Contracts specify them. Similar arrangements are in effect with the competitors' airships. Broadcasting football, Kamm aims for one blimp pop in the first half, two in the second. And resounding pops they must be, for Goodyear accepts them as payment for services rendered. No money changes hands. Forget Wayne Gretzky to the LA Kings. This is the biggest trade in sports.

Aboard the blimp there is very little fan-like spectating. There's little time. No big-screen views. No popcorn. No beer. No bathroom, for that matter. In the rear of the gondola, in a storage area behind a second camera positioned to take an inside shot of the blimp, one can, if one must, grab a specially outfitted small black hose.

By the end of the third quarter, Moran is eyeing the horizon behind the capitol dome. The ceiling is falling. A blanket of low clouds is sweeping in from the west. He checks his radar screen. No rain yet. In the truck, Wittman's thinking the same thing: "First thing you get on the radar you tell me." Kamm has alerted everybody he wants to "go to inside the ship at the beginning of the fourth quarter," and Wittman's looking to sell a shot of the radar screen.

In preparation for the inside shot, Moran reaches for Jonah Carver's satin jacket, which he asked the ground crew chief for prior to boarding. He drapes it neatly over the back of the passenger seat beside him, the words "Goodyear" and "Houston, Texas" facing the camera. Moving to the back of the ship to operate his second camera, Hampton throws a switch that provides additional lighting.

A Notre Dame interception postpones the shot. Finally, midway through the period, Kamm works it in. "Okay, ready the blimp. Dissolve to the blimp." Hampton starts fairly tight on the blimp's radar screen ("It looks like the rains have passed," says Jackson) and then widens, cueing Moran: "Turn around, John." Moran's lips move in a classic "Hi Mom" greeting. And it's back to the game, which Notre Dame manages to squeak out in the final minute, thanks to help from higher up than the blimp. A near-interception bounces off a Michigan State player and becomes a goal line completion that sets up an improbable winning score. The last televised view from the blimp shows the still-full stadium, and across this image is superimposed the final score—Notre Dame 20, Michigan State 19—and then the sponsors' credits.

"Thank you videotape. Thank you Karen . . . " One by one Kamm thanks his team. "Thank you blimp."

Hampton starts the winch to raise the camera. "John, the ball is up," he announces. Moran points the ship back toward the airport and into a 30-mph headwind. From a half-mile away, the ground crew can be seen on the runway. Moran angles the ship down, heading into the wind. A small crowd of onlookers stands by the airport security fence. Moran cuts the engines, then throws the props into reverse. Two trios of crewmen dressed in rain gear reach for the dangling noselines and begin guiding the ship off the runway to the grass and the awaiting mooring mast. Moran sees four fingers held aloft (four feet to coupling). Three fingers. Two. One. *America* is on the mast. Moran reaches for his logbook and enters the time of his return: 19:14. Under remarks, he writes: "MSU Notre Dame." He does not include the score.

TOM NEBBIA

Veteran pilot John Moran was surprised to learn how tough airship piloting can be.

Moran heads off in search of a bathroom. The crew begins removing the camera gear, which two days later will again be aloft, this time aboard the *Spirit of Akron* serving "Monday Night Football" over Giants' Stadium in New Jersey's Meadowlands. *America* will leave Lansing at 9 a.m. tomorrow, stopping over in Joliet, Illinois. Destination: Cedar Rapids, Iowa, and the annual Farm Progress show.

By late Sunday morning, the crew has dismantled and stowed the mast, retrieved all the scattered ballast bags, stowed themselves inside the bus, van, and truck, and driven off. There will remain a reminder that the blimp was here. Visible to keen-eyed pilots is a circle nearly 170 feet in diameter worn into the grass—the tracing made by the ship's lone wheel as five days of changing winds pushed the airship, like a giant windsock, through all points on the compass. The Goodyear blimp has left another footprint.

ELECTRONIC

In modern air combat, the first weapons used can't be seen or heard.

by Fred Reed *Illustrations by Web Bryant*

It is shortly after eight o'clock one evening in late 1972, and the humid gloom settling over Udorn, Thailand, is shaken by thunderous afterburners as dozens of F-4 Phantom fighter-bombers take off. Originally designed as naval interceptors to defend the fleet, the two-seat, twin-engine jets are now configured for attack and laden with ordnance. They form up and head toward a rendezvous with a gathering of KC-135 tankers waiting somewhere over Laos. Dozens of F-4s from other bases converge in the area, all of them thirsty for fuel. Attached under their wings, hardly distinguishable from the bombs and missiles there, are oddly shaped pods.

After they drink from the tankers, the formations turn and cross into North Vietnam. The officers in the back seats of the jets begin to flick switches that activate systems in those under-wing pods, which are packed with electronics. Now the F-4 crews are beginning to hear new sounds coming through their headphones: an occasional beep from enemy radar tells them that they have just become glowing symbols on North Vietnamese radarscopes. A search radar's beam sweeping the sky

WAR

Bulging with electronics pods and bulbous antennas, EF-111A Ravens are equipped to fight a silent battle.

from the ground has spotted them.

The F-4 crews switch on the "music"—jamming signals transmitted from their electronic warfare pods and designed to confuse or blind the search radars. The beeps become more rapid as the radars narrow their scans to focus on individual jets. Each back-seater watches his instrument panel closely as the radar homing and warning (RHAW) receiver begins to light up. His airplane is represented at the center of the circular screen, with glowing lines radiating toward each radar transmitter.

While the electronic warfare officers in the back seats concentrate on their demanding task, the pilots scan the emptiness of the night for a sudden orange glow in the cloud layer below. This burst of light would mark the booster ignition of a surface-to-air missile (SAM) leaving its launch rail; seconds later the crew would hear the distinctive sound—the "rattlesnake"—of initial guidance commands from the SAM command site to the missile. The missile creates a dark hole within the surrounding glow of the rocket exhaust. After it clears the cloud deck, the missile

(Continued on p. 88)

RADAR: THE INVISIBLE WEB

An intruder meets an electronic barbed-wire fence.

As an aircraft intrudes into heavily defended airspace, radar pulses from dozens of antennas strike the airplane from all directions. These radars control hundreds of anti-aircraft missiles and guide hundreds of interceptor aircraft toward the attacking force. If the intruding airplane cannot hide from these radars, it will be destroyed in minutes.

All radars operate on the same basic principles. The radar antenna emits a pulse of high-frequency radio energy that travels to the target at the speed of light. Part of the energy is reflected by the target and returns to the radar receiver. By measuring the time it takes a pulse to reach the target and return, the radar determines the target's range. The direction of the radar beam determines the target's azimuth. In general, all defensive radars work this way, although they may be designed for one of three specialized functions: early warning, search, or fire control.

Early-warning radars are usually very large, powerful, and few in number. They sit well back from the border, operate at ranges extending hundreds of miles, and generate vertical fan-like beams that sweep a large section of the sky. Designed to detect an attack as early as possible, these radars then hand off incoming targets to local radars, which stand the best chance of shooting the target down. Some early-warning radars have recently been developed that are capable of detecting targets beyond the horizon by bouncing signals off the ionosphere, which has the potential to extend the range of the radar to thousands of miles.

Search radars are located with batteries of individual missiles. Their range, typically in the hundreds of miles or less, allows them to detect an intruder in time to track it and fire a missile. Search radars also scan the sky with a fan-shaped beam.

Fire control radars, also part of a battery of missiles, have narrow beams like those of a searchlight. Once the battery's search radar has found a target, it points the fire control radar beam, which locks on to the target and feeds data about the target's range, speed, and direction to the fire control computer.

When the missile is fired it may actually "ride" the beam of the fire control radar to the target or fly an intercept course using information acquired by the control radar and radioed to the missile. Another type of missile, known as semi-active homing, seeks the reflected radar from the target to home toward it. Yet another active missile type has its own radar, which seeks the target when the missile gets close enough to it.

A well-designed air defense system has missile batteries placed densely enough so that their areas of coverage overlap. The Soviets, knowing that numerous batteries could be destroyed in battle, use many more than are necessary for minimum coverage. They also use many different kinds of missiles with very different radars operating at a wide range of frequencies, making it difficult to jam all of them.

It is important to understand, though, that the radar's range is not clearly defined but can vary with atmospheric conditions and the amount of energy the target reflects. The reflected energy of an airplane depends on a characteristic called its radar cross-section (RCS). A B-1B, which has a low RCS, may slip undetected through a radar that would spot a high-RCS airplane. The B-2 Stealth bomber is designed to present an extremely low RCS.

Radar pulses have specific characteristics such as frequency, duration, and pulse repetition frequency—the number of pulses transmitted per second. Pulses can be coded in ways that make them difficult to jam; there are even low-probability-of-intercept (LPI) radars that use various techniques—for example, irregular pulses that appear to be random noise—to prevent the target from detecting the radar. Consequently, the intruder faces a very complex environment.

Modern radars also rapidly change their characteristics in ways that make jamming difficult. Some radars are "frequency-agile," hopping around the band of frequencies many times each second. Certain kinds of radars with "phased array" antennas steer and shape their beams electronically. They can move the beam around deceptively so the target never knows when the radar will look at it.

Computers are also used to link missile batteries and launch whichever has the best shot. The exploitation of computers, however, is a double-edged sword because of one simple reality: computers are electronically vulnerable. Any attacking force is likely to fire nuclear missiles ahead of itself to clear a path and disrupt the defenders. Nuclear bursts generate ionized clouds that block radar, and when the explosions are set off at high altitude, the enormously powerful electromagnetic pulse of a nuclear burst can fry delicate electronic circuits over a wide area. The difficult and expensive problem of completely protecting electronics from such pulses remains to be solved.


(1) MEASURE
• time
• direction
• frequency
• pulse repetition
(2) IDENTIFY
• search library
• match
• rank
(3) RESPOND
• decision A
• decision B
The computer picks the best jamming technique and retaliates.
The computer identifies each radar and ranks it by degree of danger.
The ECM computer analyzes the incoming radars.

COUNTERMEASURES:
LIGHT-SPEED REFLEXES

An ECM system reacts faster than any human could. It has to.

In order to try to hide from the radar, an intruder entering hostile airspace flies only a few hundred feet above the ground. Even if the radar can see the airplane, it may be lost in "ground clutter," the reflections from nearby terrain. (High-flying radar-carrying airplanes like the Airborne Warning and Control System—AWACS—and its Soviet equivalent, the Ilyushin Il-76 Mainstay, are able to look down and spot an airplane flying low.) The intruder must react to the dozens of radars seeking to detect it by responding almost instantaneously, and because these responses must occur in microseconds, the human operator plays almost no role.

The electronic countermeasure (ECM) computer's first job is to sort into specific radars the millions of pulses arriving at the aircraft each second. In the most sophisticated systems, the ECM computer measures when a pulse arrives at four different antennas and calculates the direction the pulse came from. This information is immediately stored in a computer file on that particular radar.

By a process called instantaneous frequency measurement, the radar's frequency is determined, and this is stored in the file along with the duration of the pulse. When the next pulse arrives, the pulse repetition frequency can be calculated and added to the file. All these events take only fractions of a second.

Having quickly compiled a dossier on the radar, the computer next looks in its library of known radars to find one that matches the characteristics it has just measured. Meanwhile, of course, it has been compiling similar files on all other radars looking at the airplane from every conceivable angle. Now the computer knows not only where the radars are but what kind they are.

The computer next ranks the radars in order of danger to the bomber. An early-warning radar is least dangerous because it doesn't fire missiles. A search radar is more dangerous because it indicates that a battery of missiles has found the airplane. A fire control radar is the most dangerous because it signals that a missile launch is imminent.

Now the computer must counter the radars, and it accomplishes this using a phased-array jamming antenna. A phased array is composed of a number of individual little antennas. By timing very precisely when a transmitted pulse is sent to each antenna, the phased array can steer a beam in the desired direction and transmit narrow beams of jamming energy directly at a radar.

The soul of elegant jamming is to use as little energy as possible. Any radar can be jammed by broadcasting enough noise to swamp it. But whereas ground-based radars can have almost unlimited power, an aircraft's power is restricted. Almost everything the ECM computer does is aimed at minimizing power: for example, jamming on exactly the radar's frequency uses less power than broad-band jamming on a wide range of frequencies. Aiming power only in the direction of the radar uses less power than transmitting in all directions. Jamming only when the enemy radar is listening for reflected pulses uses less power than jamming continuously. The ECM system even matches its jamming signal to replicate the correct RCS for the angle of the interrogating radar beam. The strength of an airplane's radar reflection varies with direction. A nose-on reflection, for example, is much less energetic than a reflection from the airplane's flank. The ECM has in its databank the correct equivalent RCS for different angles, and on that basis it adjusts the strength of the jamming signal.

Another technique, deception jamming, feeds false information rather than trying to blind the opposing radar. In one method, called "range-gate pull-off" (RGPO, pronounced "rigpo"), a radar tracking the intruder calculates the aircraft's range by timing the round trip of transmitted pulse and return reflection. To fool the radar, the ECM waits until the radar pulse arrives, then transmits a pulse of its own that looks exactly like a reflection only stronger. The radar thinks this false pulse is the reflection. After the next radar pulse, the ECM sends the false pulse just a bit sooner than the real reflection would have gone. Because the reflection seems to have arrived sooner, the radar calculates the range to be shorter than it really is. The bomber continues the cycle, reducing the range incrementally until it stops, leaving the radar puzzled. The bomber literally seems to disappear, forcing the radar to reacquire its target, whereupon the ECM system starts the routine all over again. This breaks a radar's tracking and makes fire control impossible.

"Sidelobe injection" is another deceptive technique. It is based on the fact that a radar transmits not only straight ahead but to its sides as well. Engineers try to minimize these sidelobes, but most radars have them. The ECM times the antenna's rotation. When a sidelobe is pointed at the aircraft, the airplane transmits a powerful phony reflection. The radar receives the fake reflection and, thinking it is coming from the beam aimed straight ahead, displays the position of the target as far from where it actually is.

Countermeasures have been invented for every measure, and counters for every countermeasure. For example, to counter the RGPO, the radar can measure the Doppler effect (the change in frequency that occurs when the source and the receiver are moving with respect to each other) to determine the actual speed of the intruder by the changes in frequency of its reflection. It compares the target's Doppler speed with the speed calculated by successive range measurements in order to determine whether it is being fooled.

will appear to a target airplane as a glowing orange doughnut seen head-on.

"My GIB [guy in back] would get so many radars that he had to detune the RHAW to show only SAM site radars," says Dana Drenkowski, a former U.S. Air Force pilot who flew F-4s on Linebacker raids into North Vietnam. Detuning the RHAW tended to eliminate the search radars, but "search radar didn't really mean much because they knew you were there anyway," Drenkowski says. "When you heard those beeps coming loud and fast and the RHAW had a three-ringer [the screen has three concentric rings, and a strong radar signal is indicated when the beam crosses all three], that was you, baby. You had a missile.

"At that point you had something under a minute to see the missile so you could maneuver against it. The B-52s had EW [electronic warfare] gear that would throw the missiles off course, but F-4s had to outmaneuver them. You had to time it just right, but you could actually make the missile tumble end over end." The problem, he says, is that the RHAW was designed to blank out all threats except the most dangerous missile in order to avoid distracting the electronic warfare officer. That meant that if they fired two missiles at your airplane, the RHAW would show only one. The other one got you.

Electronic warfare is like that: a series of measures, countermeasures, and counter-countermeasures. These tricks against tricks all rely on the parts of the electromagnetic spectrum that no human can sense without an electronic box that converts the invisible and unhearable into light and sound.

In recent decades electronic warfare has come to be the primal technology of modern air warfare. Without good EW, you don't survive in the air. That point may have been brought home most sharply to the Israeli air force when EW caught them by surprise in the 1973 war. After suffering heavy losses from Soviet missiles and electronically directed guns in the first days of that conflict, the Israelis discovered that to fly without electronics is to not fly at all—almost every airplane you send up gets shot down. The Israelis hurriedly installed jamming gear and survived. Now Israel aggressively markets its own homegrown EW gear.

The rise of electronic warfare to preeminence began in World War II, when radar (radio detecting and ranging) was first extensively used to detect aircraft and ships. Both sides raced to develop new radars and countermeasures that would blind their adversaries. The British concentrated on a coastal search radar system to guide their fighters toward approaching Luftwaffe bombers; the Germans focused their development of radar on directing anti-aircraft guns. Winston Churchill called it "wizard war," and it was a race the British are generally credited with having won.

Radar was quickly adopted by the U.S. Navy in the Pacific, where it virtually eliminated any hope of surprise by the Japanese. Even the raid on Pearl Harbor had been detected and duly reported by an Army radar operator, but the reality seemed so unthinkable that no defensive measures were taken.

With the advent of the anti-aircraft missile guided by radar, the importance of EW rose another notch. Previously, radar had been chiefly a means of detection, after which the intruding airplane was intercepted by another airplane flown by a pilot who simply used his eyes to find the target and fire at it. The Korean War led to radar-based fire control systems aboard interceptors, which began directing the guns or aiming volleys of unguided rockets that fanned out like a shotgun blast. Fired from the ground, a radar-guided missile seemed to appear from nowhere. Unless a pilot was warned, he could not evade it.

During the 1950s, jamming gear, which had first been carried aboard aircraft during World War II, was carried by long-range bombers as a defense against radar-guided missiles. The deadly SA-2 missiles the North Vietnamese used against U.S. jets during the Vietnam War led the United States to install jamming pods aboard its fighter-bombers.

An unending contest between measure and countermeasure ensued: missiles homed, aircraft jammed, missiles homed on jamming or figured out how to distinguish spurious signals and ignored

GRUMMAN CORP.

The F-4G Advanced Wild Weasel detects radar, then fires a variety of anti-radar missiles to destroy it.

MCDONNELL DOUGLAS

them (see "The Invisible Web," p. 84). Finally, because the new electronic weapons reacted nearly instantaneously, pilots could no longer manage the many complex tasks associated with war waged in the electromagnetic spectrum. The spectrum is too large, the tasks too many.

It has now reached the point where bombers and even fighters have become flying committees of computers to whom the pilot sometimes is just an auxiliary. The electronic countermeasures console of the B-1B bomber is conspicuous for the absence of dials and switches; the operator simply doesn't do much. In today's EW suites, dozens of computers with processing power unimaginable 15 years ago cooperate in hierarchical order (see "Light-Speed Reflexes," p. 86). Software, however, has become a major stumbling block in the development of large military systems—often being more difficult to develop than the hardware.

Over the years, two fundamentally distinctive approaches to electronic warfare have become apparent, one associated with the Soviets and the other with the United States. To put it simply, the Soviets went with brute force, the United States with sophistication.

The Soviets overwhelm radars and countermeasures with higher transmitter power. The MiG-25 Foxbat-A, for example, is designed with large "Fox Fire" radar, which is capable of burning through hostile jamming.

The U.S. advantage in miniaturization, microcircuitry, and software enabled American designers to produce complex EW systems requiring less power and space. U.S. aircraft—even small fighters—usually carry their own EW gear, although there are exceptions. The United States has specialized jamming aircraft as well: the EA-6B Prowler, a modified A-6, accommodates high-powered electronic jammers.

The equipment aboard an EA-6B Prowler can play havoc with the electronics of an adversary.

But the U.S. pursuit of sophistication raises its own danger: the loss of quick response. As sophistication increases, the difficulty of managing the development of the systems rises as sharply as the expense. An EW system for countering a specific threat might take years to develop, yet the threat could change overnight. But the advent of the reprogrammable microprocessors now permits electronic countermeasure systems to be quickly reprogrammed to meet changing threats without the major hardware changes that were needed on early systems.

The B-1B is perhaps the most infamous example of the troubles that can beset development of onboard defense systems. It had, and apparently continues to have, serious problems that appear resistant to quick or cheap fixes. The difficulties exemplify those confronting engineers who try to design quickly and on the leading edges of technology. General Larry Welch, former Air Force chief of staff, explained what happened this way: "The problem was threefold. First, the system was badly over-spec'ed. We had gone to [the Strategic Air Command] and said, 'What do you want the defensive avionics to do?' and SAC of course had opened with five no-trump. They said, 'We'd like to automatically detect and jam everything from half a gigahertz to 18 gigahertz [radar frequencies].' So we went to the contractor, and he said, 'Oh yeah, we can do that.' Nonsense. We *still* don't know how to do that.

"The problem really was inexperience," Welch said. "We have not amassed a community of experts who can immediately recognize what's reasonable and what's not. So we started out with a totally unreasonable, unchallenged requirement."

The second problem was with integration. "The individual black boxes worked to their specs," said Welch, "but when those boxes were integrated, they didn't do anything like what they were supposed to do . . . . Had we ordered a complete system instead of black boxes, the problem would have been immediately obvious."

Today U.S. forces and their allies in the Mideast confront a new irony: air defense systems of their own design are under the control of Iraq. The Soviet threat may be diminishing, but regional conflicts continue to flare. The brisk trade in defense systems means any nation can acquire current electronics.

But not all nations can build them. New materials such as gallium arsenide call for advanced manufacturing techniques. Most important, electronic systems require millions of lines of computer code. Those who lead the field today will likely be the ones who develop the EW systems of tomorrow. It takes advanced skills and lots of money, and electronic warfare is a game only the most technologically advanced nations play.

DAVID NANCE

Soviet Booster

Art Dula wants to launch your satellites aboard Russian rockets. There's only one catch: the U.S. government won't let him.

by Tom Huntington

Art Dula's office has an unbeatable view. Beyond the glittering glass-and-steel highrises of downtown Houston, you can see the flat Western countryside marching on toward the horizon and disappearing into the early autumn haze. Far off in the distance, the turtle-back hump of the Astrodome rises up from the plains. It's a Texas-size vista; you feel as though you could simply open the window and lob a satellite into orbit.

Such an epic panorama seems at first glance an incongruous backdrop for this office's tenant. Art Dula—round of face, thin of hair, sporting a dapper mustache—has the look of a small-town banker, the fellow with the vest and green eyeshade who spends his days snapping out singles, tens, and twenties. But look around his office: There are models of the U.S. shuttle, the Soviet Buran shuttle, a European Ariane rocket. A small table by one window is covered with Soviet medals, plaques, and awards. On the credenza sits an autographed photo of Neil Armstrong. One object in particular catches the eye—it's a corroded metal structure that looks like a porthole cover salvaged from the *Titanic.* "I bet I'm the only lawyer in Houston with one of those in his office," Dula says. It's a safe bet. The object, it turns out, is a canister that had been attached to a Soviet spacecraft and launched into space.

From his office high above Houston, SCC founder Art Dula tries to market Soviet space services in the U.S. Some Western satellite users would like to take the company up on the offer its poster makes (right).

Clearly, this is the office of a man whose interests extend well beyond the local, well beyond the national.

Dula's company, the Space Commerce Corporation, is in the business of arranging for U.S. satellites to be launched aboard Soviet boosters. Unfortunately, this scheme has a whopping Catch-22: U.S. export policy, in this case under the control of the Department of State, presently classifies satellites, boosters, and other space hardware as munitions. And munitions cannot be exported to the Soviet Union.

What Art Dula is trying to do, then, 69 stories above the boom-or-bust city of Houston, is pry open a very stubborn launch window.

In 1989 Dula signed an agreement with Glavkosmos, the Soviet agency formed in 1985 to commercialize the space program, in which SCC became the sole agent in the United States for marketing Soviet space services. The company now markets everything from launches aboard the heavy-lift Proton booster to knickknacks like lapel pins. Dula even envisions cosmonauts plugging products from the Mir space station. "Think of the lift it would give to worldwide sales of your company's line of running shoes if cosmonauts were filmed wearing them while exercising on the space station's treadmill," reads one of SCC's brochures. " 'TRAVEL LIGHT,' the slogan might say."

A trifle outlandish, maybe, but a few years back it would have been the stuff of stand-up comedy. As recently as 1984 Dula himself was speculating to a *Houston Post* reporter on how the Soviets would justify shooting down a space shuttle. But in the years since, the Berlin Wall has fallen, the Eastern Bloc has started to collapse, and the president of the Soviet Union has been awarded the Nobel prize for peace. Today the Soviets openly admit they are starved for hard currency. They have already sold their launch services to India, France, and Germany; they've lofted spacecraft bearing advertising banners, and last December they gave a Japanese journalist a ride on Mir in exchange for $12 million. So why shouldn't cosmonauts hawk sneakers made in the U.S.A.?

William Wirin, SCC's executive vice president and chief operating officer, sees the situation this way: Socialism, he likes to tell his audiences, is "the long, hard, bloody road between capitalism and capitalism."

A company that sets out to turn a profit on the products of a Socialist system sounds like a company of ultimate capitalists. But to fully understand Space Commerce Corporation, you must keep in mind that its founder is an unabashed space nut. Reared on the stories of Robert Heinlein, Dula subscribes to the Gerard O'Neill school of thought that exploring space is an inevitable step in the human saga (see "Gerry's World," April/May 1989). "It's a basic evolutionary drive," he says of the need to get into space.

In most young men that drive fades during adolescence, when another rears

its head. Dula, capitalist that he is, found a way to make his interest pay. "I entered law with the idea of becoming a space lawyer," he says. His legal work has included the incorporation of several space-related companies, including Space Services, Inc., responsible for the first commercially licensed launch in the U.S. He has also taken on more, uh, untraditional work. In 1984, as part of a publicity stunt, he drafted an application for Lamar Savings and Loan to open a branch on the moon. (The Texas S&L commissioner refused to consider the application; Lamar was later declared insolvent and its president indicted on 14 counts of fraud.)

In 1985 Dula founded SCC, a company run by an informal group of like-minded lawyers who work out of their own offices in Houston, Colorado Springs, Washington, D.C., Montreal, and Denver. Originally the company pursued commercial space interests here in the United States. But in his dealings with NASA, at the time the only game in town, Dula kept running into disappointments. "The United States space program is not interested in getting into space," he says. "Its purpose is to be a technology developing program."

"For years we've said, 'Come be a capitalist.' Now we say, 'Oh no. That's competition. We can't stand that.' "

He has a point. The U.S. program produces craft that are highly complex but tend to be balky and fragile—hothouse flowers. The Soviets, by comparison, have been using the same basic, somewhat plodding boosters since the dawn of the Space Age. The Soyuz rocket, used since the mid-1960s, has notched close to 1,300 successful launches. By keeping to the tried-and-true, the Soviets have consistently outlaunched the U.S. The Soviets have a functioning, manned space station. The United States does not. In 1989 the Soviets staged 74 launches. The rest of the world combined managed 27.

TOM HUNTINGTON

A small table in his office testifies to Dula's contacts with the Soviet space program (above), as does his opportunity to model a cosmonaut spacesuit (below).

The Soviets aren't racking up all those launches for the sheer glamour of spaceflight, of course. Most of the time they're just taking care of business: For one thing, Soviet satellites don't last as long as Western ones, so they need to be replaced more often. And the Soviets rely more on retrievable surveillance satellites, which are sent into orbit for a short time and then brought back so their film can be examined.

All this practice makes, if not perfection, at least high degrees of reliability and flexibility—characteristics that in recent years have come to hold special appeal to U.S. space entrepreneurs. In the 1980s, NASA and its Capitol Hill advocates attempted to justify the enormous cost of the shuttle program by making the vehicles the sole access to space. When *Challenger* exploded in 1986 and the shuttle program stalled out, the United States was left without a ride into orbit. Consequently, President Reagan took the shuttle out of the commercial launch business, opening up the field to private firms.

Today the U.S. heavy-lift commercial effort is dominated by three companies and their expendable boosters: General Dynamics (the Atlas), McDonnell Douglas (the Delta), and Martin Marietta (the Titan). Their launches are expensive, compared with those made by Soviet boosters, and relatively infrequent. In 1989, the U.S. heavy lifters made two commercial launches; last year, the total scheduled was 10.

Unhappy with the restrictions on getting into space, Dula got to thinking about what the Soviets were doing. Through meetings of the International Institute of Space Law, he had been in contact with lawyers from the Soviet Union. "I always ended my speeches with 'When are you going to sell your rockets?' " he recalls. "And after the 1985 meeting, one of the Russian members came up to me and said, 'Art, we're going to do it.' " The following year Dula met Glavkosmos director Alexandr Dunayev. "I told him I'd like to buy some of his rockets," recounts Dula. "He essentially said, 'Fine. Sign the check. We'll do it.' "

The U.S. government, however, will not. Officially there are two main reasons. One is the possibility that the Soviets will study any satellites they launch and appropriate the technology. The other is the suspicion that the Soviet government is artificially underpricing U.S. commercial launch services in an effort to get business.

In 1987, SCC tried to arrange the launch of two Hughes communications satellites aboard Soviet Protons. But not even Roger Smith, chairman of Hughes' parent company, General Motors, could win U.S. approval for the scheme. He wrote to then-secretary of state George Shultz to try a bit of friendly persuasion. Shultz refused to budge. "We must never allow the United States to become dependent upon the Soviet Union for access to space," he responded sternly.

Two years later another company, the Energetics Satellite Corporation of Englewood, Colorado, enlisted SCC's help in obtaining Soviet launch services. Energetics' plan is to loft a series of tracking satellites as secondary payloads aboard Protons. The idea has a number of advantages. By loading its small satellites behind other customers' larger payloads, an alternative the Big

COURTESY ART DULA

Three haven't yet offered, the company could keep costs down. In addition, the Proton has the ability to go directly to geostationary orbit, without having to enter a temporary transfer orbit. And then there's that Soviet reputation for reliability. "We found out that if we were able to actually do this we would be rewarded with the lowest insurance rates available," says Energetics' president, Jordan Smith. "It's a reliable launch vehicle. And the insurance rates are not being set by the Russians. They are set by independent companies trying to make a profit. Rates are being determined based on track record."

Smith is unimpressed with the U.S. government's technology transfer objections. "There is no danger," he says. "We can prove we will not transfer any technology whatsoever. The satellite doesn't have a computer system, except for station-keeping purposes. It's not as complex as the ones the Russians have already."

According to Dula, the technology transfer issue is no more than "a red herring." The Soviets, he says, have agreed to forgo any inspections of U.S. payloads they launch. Furthermore, they have promised that U.S. technicians will be free to keep constant watch over any American satellite while it is inside of the Soviet Union. The real hitch, says Dula, is that the Big Three's commercial launch monopoly benefits both the companies and the U.S. government. "These companies are major military contractors," he says. "Every time they build a civilian launch vehicle at whatever price, it lowers the overhead on the vast majority of their vehicles, which are military launchers."

Dula dismisses the question of underpricing just as quickly. "We attempted to overcome that argument by saying, 'Okay. If that's your problem, if you really think we're launching at a subsidized price, we will launch at your price. We'll leave our price blank in the contract and the U.S. state department can fill it in.'

"For so many decades we've said, 'Come and be a capitalist, join us in our system, trade with us,' " he continues. "And the Soviets say, 'Okay. We've got this one area where we're good enough to do it. We're going to do it.' We say, 'Oh no. My God, that's competition. We can't stand that.' "

Sometimes the Soviets hurt their own cause. Always very secretive about their space program, they kept the Proton under such tight wraps that no photos of it were ever released to the West until 1984, almost 20 years after its first launch. And when embarrassing failures have occurred, the Soviets have always been a tad hesitant to inform the world, which doesn't make potential customers happy. Although they've gotten better under *glasnost,* in the bad old days it was not uncommon for the Soviets to refuse to acknowledge an accident at all (see "Disaster at the Cosmodrome," December 1990/January 1991). As recently as 1987, when the fourth-stage failure of a Proton left three navigation satellites stranded in useless orbits, Glavkosmos sent Dula a wire assuring him that "three artificial Earth satellites were successfully launched by a Proton launch vehicle into high elliptical orbit on Apr. 24."

Admitting failure is still a struggle. After a liquid-fueled Zenit booster blew up on the pad last October, the Soviets

DAVID NANCE

Soviet space goes commercial: Dula hopes to see this logo painted on the side of a Soviet rocket.

waited a full week to disclose the fact, a delay some speculate was due to military pressure to keep a lid on the news.

Public scrutiny, of course, is a new concept in the Soviet Union. When Dula first traveled there in 1987, the visit opened eyes on both sides. "I had to apologize for my own arrogance," Dula recalls. "I thought I knew all about Russia, all about their space program. In fact, I'm very surprised I got through that first set of negotiations. I told them the Proton was a museum piece and they were lucky to get me to sell it. I made one of the engineers so mad he stopped talking to me."

For its part, the U.S. government may at last be starting to relax its bristly stance on commercial launch cooperation. In 1989 the Bush administration agreed to allow the Chinese to launch up to nine Western satellites aboard their Long March booster over the following six years. "With the Chinese agreement, the technology transfer argument has essentially been blunted," says SCC's William Wirin. "Once the Chinese were authorized, you have to argue that the Chinese aren't as smart as the Soviets, and I don't think that's going to play in Peoria." The state department disagrees: "We have stringent technology transfer agreements with the Chinese regarding the interface of satellites with boosters," says Scott Miller of the office of trade policy, referring to the fact that the satellites' technology was carefully obscured from the Chinese. Some suggest that the real reason the Chinese were granted permission to launch was that they agreed to stop selling Silkworm missiles to Iran, a concession the Chinese deny.

Although the state department still considers the Soviets a strategic threat, it has allowed one U.S. company to send a scientific payload to the Soviet Union for launch. In December 1989, Massachusetts-based Payload Systems Inc. flew a protein crystal growth experiment aboard the Mir space station for 56 days. "We applied for and received an export license after it was reviewed by the Department of Defense and the Commerce Department in February 1988," says Payload Systems senior vice president Vinit Nijhawan. The company also dealt with the Soviets directly. "We did it very quietly," says Nijhawan. "We didn't publicize it a lot. Space Commerce is very publicity-oriented. When they introduced their agreement with Glavkosmos, do you know how they did it? They held a press conference in Washington." That, he implies, is not really the best way to get things done in Washington.

Another sign of increasing U.S. flexibility appeared last August, when the Bush administration allowed United Technologies' USBI division to take part in the planning of a spaceport at Cape York, Australia, slated as a launch site for the Soviet Zenit booster. The administration stopped short of granting permission to launch U.S. satellites from Cape York, but in effect it has allowed the U.S.-Soviet courtship to proceed as far as the front-porch swing. "The U.S. government has now acknowledged that the Soviet space program can enter the world market," says Wirin.

"SCC is very publicity-oriented," says Nijhawan. That doesn't always go over well in Washington.

For SCC, that's the good news. The bad news is that as part of the Cape York agreement, the United States reiterated its ban on all launches of U.S. satellites within the Soviet Union.

Space Commerce Corporation has a number of other schemes up its sleeves. It hopes to circumvent technology transfer objections by launching Protons from a planned commercial

launch facility in Florida, though those hopes may be dashed by the Cape York agreement, in which the U.S. stipulated that the Soviet Union must limit its launches of Western commercial satellites to one site outside the U.S.S.R. The company also wants to market launches of small scientific payloads aboard a future booster based on the Soviet SS-20. That missile has been eliminated by the Intermediate-range Nuclear Forces treaty, but its production facilities still exist. In addition, SCC recently began marketing Earth imagery produced by the Almaz 1 satellite, scheduled for launch this winter, and data from the Almaz prototype, Cosmos 1870, which orbited from 1987 to 1989.

Last December, SCC put together a deal enabling Houston-based Space Travel Services Corporation to send an American to Mir. In a new twist on the concept of space commercialization, STS announced it will pick its guest cosmonaut in a sweepstakes-style contest in which entries can be phoned in on a 900 number at $2.99 per call. STS's Jim Davidson says part of the idea is to increase awareness of space, but he openly admits, "Our intent is to make as much money as possible." The phones will have to ring incessantly for that to happen: STS paid more than the $12 million a Japanese broadcasting company ponied up to send one of its journalists on a similar trip last year.

In brokering the deal, Dula dealt directly with Energia NPO, the bureau that developed Mir, rather than Glavkosmos. Observers of the Soviet space program believe that Glavkosmos' marketing role is slipping away. Booster manufacturers have been given some of the work that once fell solely to Glavkosmos; during the Cape York negotiations, says USBI spaceport director Dick Rubino, the Ministry of General Machine Building gradually took over Glavkosmos' function. Dunayev won't comment on his agency's fate except to allow that it may be affected by "further development and reorganisation of the whole governmental structure." But some are convinced that within a year, Glavkosmos will be eliminated. Dula is undaunted by the speculation. If the agency is purged, he says, another will take on its role.

Dula is not unmindful of the possibility of failure. Back in the late 1970s, he introduced space-minded financier David Hannah to a young man named Gary Hudson, who was eager to try his hand at building a rocket. With a $1.2 million investment from Hannah, Hudson and a team of engineers set to work, eventually producing a liquid-fueled vehicle they called the Percheron. But during the first engine ignition test, conducted on a Texas cattle ranch in August 1981, a fuel valve crusted over with ice, causing the rocket to be blown hundreds of feet into the air. Today, a twisted piece of the Percheron—once hoped to be the first commercial rocket in the United States—hangs on a wall in Dula's office.

A decade after the ill-fated test, Gary Hudson is still trying to carve himself a niche in the U.S. commercial launch business, but he wishes Space Commerce Corporation luck. "I'm happy to see them stick it to the establishment," he says. "It wakes people up over here. NASA is sleepwalking into the future. There's no real competition."

Spoken like a true capitalist. Dula would be pleased.

BLUE PLANET®

A new IMAX film teaches us that there's no place like home.

by David Savold

Astronauts have a reputation for keeping their cool, but sometimes they can't help but surrender to a feeling of child-like wonder. Shannon Lucid, who journeyed into space in October 1989, proves no exception in the new IMAX movie *Blue Planet.* When Lucid gazes from the space shuttle *Atlantis* at her planet floating in the blackness of space, all she can utter is an awestruck and unselfconscious "*Wow.*"

That one word provides the perfect introduction to a film that offers a perspective on our planet once reserved for astronauts only. From the 200-mile-high orbit of the shuttle, Earth exhibits a continuous procession of the azures and aquas that dominate our watery world and give the film its name. Explaining that the ocean was created by erupting volcanoes, the narrator notes, "Its blueness came out of the Earth itself."

This blueness has always distracted astronauts in space. From the very first days of manned spaceflight, astronauts have returned from space with a new appreciation for Earth's beauty. In one sequence in *Blue Planet,* an Apollo 16 astronaut stands on the moon, and the contrast between the barren, lifeless lunar surface and the blue, cloud-swirled Earth rising over his shoulder makes its point eloquently.

Blue Planet, which includes footage from five shuttle missions, is a collaboration of the National Air and Space Museum, NASA, and the Toronto-based Imax Systems Corporation, with funding from Lockheed. But the film's opening credits leave no doubt that the astronauts were behind the camera. In a way, the 42-minute film is like a compilation of movies from the astronauts' favorite vacation.

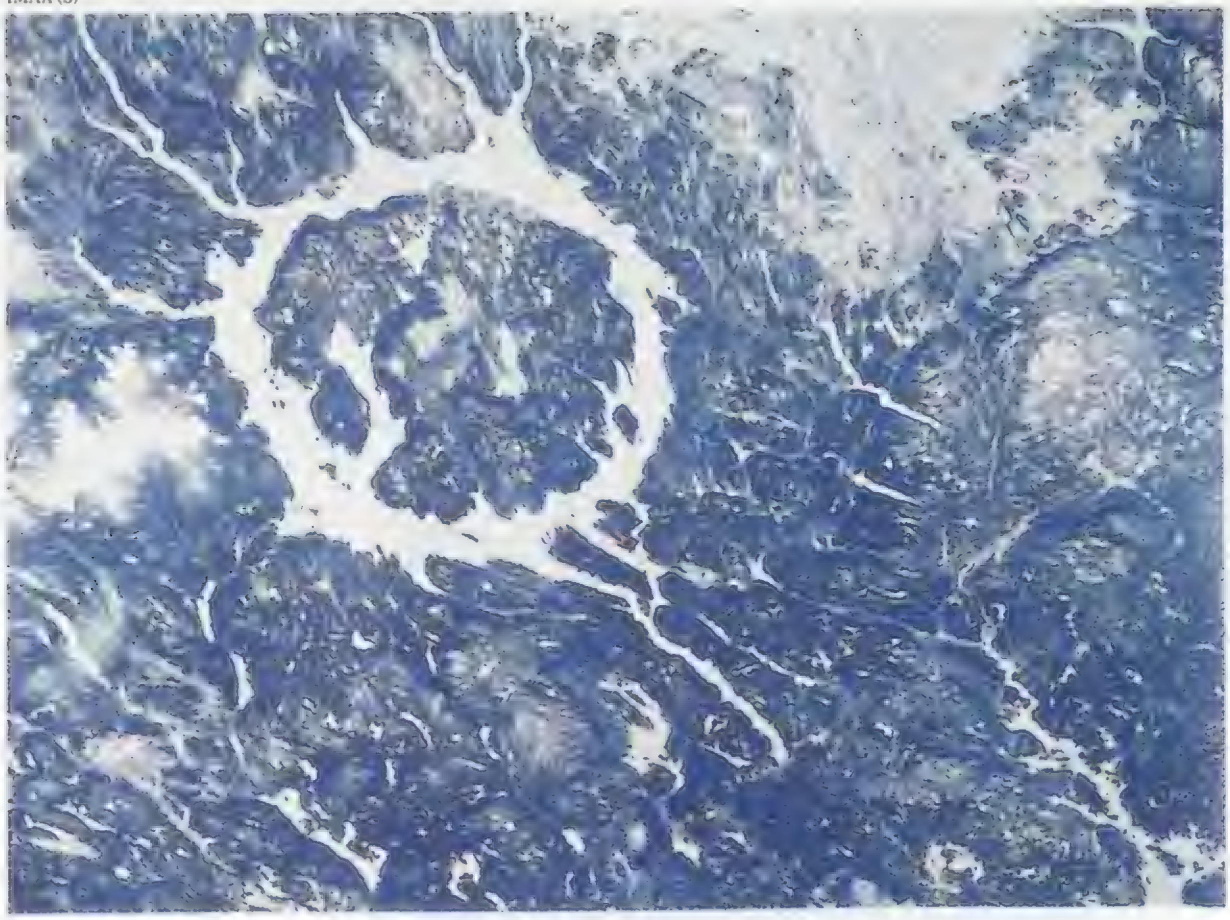
To film *Blue Planet,* each astronaut took a crash course in cinematography, receiving 25 hours of training with the IMAX camera. They learned how to use four different lenses, how to light the cabin, how to frame a shot. On Earth the camera weighs 80 pounds but in orbit—though still bulky—it weighs nothing. Eventually the camera became something of a mascot to the crews. Its size and color called to mind a black labrador retriever, and the astronauts bestowed the camera with the nickname "Max."

The astronaut/filmmakers' biggest challenge wasn't mastering cinematography, it was coping with the weather. During the missions NASA transmitted satellite photos of current weather patterns. The most difficult target to photograph was the smoke from slash-and-burn rainforest defoliation. The pervasive cloud cover over the Amazon eventually forced *Blue Planet*'s editor to use still photographs of the burning rainforest taken during an earlier mission.

Astronauts say that from space, Earth's most striking feature is the amount of water covering the planet. From orbit we can also get a wider perspective on how Earth supports the life that exists almost everywhere—from the oceans to the grasslands of the Serengeti (below).

IMAX

IMAX (3)



Factors beyond our control sometimes affect the planet. Some 30,000 years ago a chunk of asteroid created a three-quarter-mile-wide crater in Arizona (below). Quebec's 60-mile-wide Manicouagan Crater is obvious only from space (right). Humans, on the other hand, are responsible for the hundreds of fires used to clear South America's rainforests (far right). The smoke is visible from orbit.

Though its large-screen format excludes *Blue Planet* from Academy Awards nominations, the astronauts' cinematography is worthy of an Oscar. Some of the most impressive shots were obtained on mission STS-31, which launched the Hubble Space Telescope. During deployment, the shuttle reached the unusually high altitude of 380 miles above Earth. This position allowed an especially spectacular shot of the curvature of the Earth, with the atmosphere outlined against the blackness of space like a thin, almost neon blue line.

But for all its dazzle *Blue Planet* is more than just pretty pictures. The film conveys a message intended to increase awareness of the environmental threats to our planet. It's a message the film's producers take seriously. "We realized from the beginning that we had to be scientifically accurate," says Martin Harwit, the director of the National Air and Space Museum, who first pitched the idea for *Blue Planet* to Imax Systems.

To help get that message across, the Museum assembled an advisory panel: Francis P. Bretherton of the National Center for Atmospheric Research, D. James Baker from the Joint Oceanographic Institutions Inc.,

Special Effects

"It is certainly the closest you'll come to experiencing lightning cracking over your head—hopefully—in your lifetime," says Steve Fitch, operations manager of the National Air and Space Museum and its 486-seat Langley theater. He's referring to *Blue Planet*'s impressive thunderstorm sequence, which, thanks to the double wonders of time-lapse IMAX photography and digital stereo, looks and feels as if it's marching across the landscape and into the theater.

IMAX stands for "image maximum," and the technology lives up to its name: a frame of IMAX film is some 10 times larger than standard 35-mm movie film, and it requires a projector the size of a small car. The water-cooled Xenon lamp that throws the image onto the screen draws 17,000 watts (the lamp in a commercial theater, by contrast, draws 1,500). The screen is five stories tall.

The Langley theater's 20,000-watt, six-track sound system is one of the best in the world. *Blue Planet*'s soundtrack, recorded on three compact discs, is played independently on a digital playback system and synchronized with the film. "By the time you listen to the thunderstorm sequence," Fitch says, "you feel wet."

conditions, including the beginning of thunderstorm season in New Mexico and Hurricane Hugo's winds in South Carolina.

In one of the film's more unusual sequences, computer animation takes the audience on a wild ride along California's infamous San Andreas Fault. Kevin Hussey and computer programmers at the digital image animation lab at NASA's Jet Propulsion Laboratory developed a dramatic piece of computer animation with the help of NASA's Cray supercomputers. Hussey and his colleagues generated 40 billion bytes of information to produce the sequence, which also simulates the 1989 earthquake that rocked San Francisco.

But it's the lofty vantage of space that provides the most dramatic view of some of the forces that threaten our planet. Above Madagascar the Betsiboka river appears red from the soil that is being washed into it from the deforested island. High over the Amazon rainforest, smoke from slash-and-burn farming can be seen extending for thousands of miles. By giving audiences a chance to see what Earth looks like from orbit, *Blue Planet* makes a dramatic point: for all its vastness, our planet is, after all, not that big, its resources certainly not infinite.

A storm system is visible behind the TDRS satellite being deployed by Discovery *(above). Such atmospheric disturbances feel violent on Earth, but from the shuttle our atmosphere appears a tenuous shield from the harshness of space (below).*

Ghassan Asrar from NASA, Barbara Valentino from the National Academy of Sciences, and Steven Soter, Patricia Jacobberger, and Ted Maxwell from the Museum.

The film's message is further developed through shots from Earth's surface, which complement the astronauts' camerawork. The perspective shifts from the shuttle orbiting 200 miles above East Africa to the Serengeti below, where herds of giraffes, zebra, and wildebeest are as dependent on a fragile life support system as the astronauts in the shuttle. To document this fragile interplay of land, water, and air, a number of crews were used to film five continents in a variety of

Space, with its unimaginable distances and unfathomable temperatures, often seems like an abstract concept to us on Earth. *Blue Planet* shows there is nothing abstract about what is happening to our home. Moviegoers will share with the astronauts a renewed appreciation for the third planet from the sun. As STS-31 pilot Charlie Bolden says, "You kind of float up in the window and look for long periods of time in amazement at what's going on down there . . . ."

IMAX (2)

Luncheon With the Queen

Whenever I was in Washington visiting the National Air and Space Museum, I'd make a small pilgrimage to the red and white Cessna 180 in which Jerrie Mock became the first woman to fly solo around the world. Mock was from my hometown, Columbus, Ohio, and in 1964 her record flight started and ended there in the 11-year-old, single-engine, 150-mph tailwheel airplane with "Spirit of Columbus" painted on the side. Each time I'd come back and see it hanging in a permanent left bank in the general aviation gallery, I'd feel a small measure of pride thinking of another pilot of my background and my gender and almost my generation at the controls. I suppose on the last few visits I was also continuing to honor an accomplishment that had long since slipped from people's minds.

One day I went to the museum and the Cessna was gone—transferred to the Garber storage facility, I was told. So I decided that I'd pay tribute to the pilot instead, look her up someday and ask her to lunch so I could see what she was like and get her autograph. I finally got around to it, 25 years after Mock landed in Columbus at the end of her 29½-day, 23,103-mile flight and wrote in her log, "It was a nice, easy trip. I'm glad to be home."

I found her through her ex-husband, Russell Mock. He had written the foreword and epilogue for her book about the flight, *Three-Eight Charlie,* but in the text he comes across as a bully, hectoring his wife from the other end of bad phone connections around the world, whipping her along verbally with a brusque "Get going!" even when storms lay ahead, all the time sternly reporting the progress of Joan Merriam Smith, another woman trying to fly around the world at the same time. Smith, who took off two days before Mock, turned what was to have been Mock's solitary adventure into a race.

When I called the number Russell Mock gave me, I was relieved to find Jerrie Mock sounding so upbeat. I hadn't heard anything about her for years, and I was a little worried that the vitality of a world record holder might have faded. But she told me that she was busy writing a murder

COURTESY JERRIE MOCK

Wedged into her Cessna 180 for a trip around the world, Jerrie Mock looked like a woman who loved to travel.

mystery and that she had recently written new material to be included in a revised edition of *Three-Eight Charlie.* She accepted my cornball invitation to have lunch at the 94th Aero Squadron restaurant at Port Columbus, the airport where she had touched down before an audience of 10,000 cheering fans.

We met and chatted at her son's house before going to eat. She had the same elfin smile I'd seen in photos from her trip, but she was wearing slacks, not the dress, pumps, and pearls she wore for the flight. She had dressed that way, she said, because of her perception of attitudes abroad about proper women's attire. The newspapers of the day referred to her (and to her rival Smith) as "the flying housewife."

I had known she was small—according to her book, she'd had to sit on four pillows and put another behind her when she flew the 180—but she seemed even smaller than the picture of her I had formed. Only five feet tall, she sat with a stool under her feet, a carved wooden one she'd picked up in Suriname on her later travels. She once owned a Luscombe, she said, and that gratified me because it was the kind of airplane I owned. She had to fly it with her toes on the heel brakes—she couldn't reach the pedals with her heels.

She was very lively, talking and laughing and using her hands to punctuate her sentences, but she was also refined. She held herself very erect and spoke precisely, taking care to express exactly what she thought.

She hadn't flown in 20 years. For one thing, she said, she couldn't afford it. In the first couple of years after the flight she'd done a lot of public speaking, appearing, in a single year, before 26 Rotary Clubs, "not to mention Lions, Kiwanises, and Seroptimists, plus ladies' clubs and church groups," but the proceeds went mostly to one of her corporate sponsors. And the day she came back, her husband quit his job in advertising, expecting her to "make him rich." She didn't, so there was "no money to put gas in the tank, no money to fly." In those same years she made other record flights, for straight-line and closed-course speeds and distances, of which she is still proud, but they cost a lot and she had to give them up. Her last flight was to New Guinea to deliver a Cessna 206 to Catholic missionaries; her last takeoff point, she told me, was the same as Amelia Earhart's: Lae Island. ("I got where I was going," she added.)

Even if money hadn't been a problem, she wouldn't have been satisfied to "just fly around here," she said. "I've got to fly over the ocean, at least the lakes." The most rapturous part of her book is her account of the Wake Island-to-Honolulu leg, when she was floating 13,000 feet over the Pacific. She became so transported by the beauty of "the foamy clouds and glowing rainbows [putting] on a command performance just for me" that she felt like the "Queen of the Ocean Skies."

She said she'd recently been spending two months of each winter in Puerto Angel, a fishing village on the west coast of

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Shown Clockwise: Grumman Hellcat (top right), F-15 Eagle, Pan Am Clipper, Space Shuttle.

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Mexico. "I can at least sit on the ground and *look* at the ocean," she remarked, adding that she hoped to move to Puerto Angel for good someday. She couldn't stand Columbus, she said. I flinched, wondering if her world travels had made her a snob. "Columbus is too clean, too safe, too conservative," she explained. "I love to go adventuring, and there's not much place for adventuring around here, except high-crime areas. No ocean, no desert, no mountains, no jungle."

The four words repeated like a mantra a phrase from the first chapter of her book, in which she describes the desire that finally overcame her nervousness as she waited on the runway to begin the record journey: "What was ahead, beyond the airport? Oceans, jungles, deserts, mountains . . . "

She'd been interested in adventuring since she was quite young. "From the time I was eight and got my first geography book," she said, "I wanted to travel." Thirty years later, when she decided to fly the family airplane around the world by herself, she saw it simply as the vacation she'd always wanted. It was only while asking for information from the National Aeronautic Association that the flight turned into something else. An official happened to mention that if she made it all the way around she'd be the first woman to do it. "I was surprised," she recalled. "I just assumed it had been done." She had mixed feelings about changing the nature of the trip, particularly when it turned into an unofficial race, as she had to forgo most of the touring and sightseeing she'd planned. Her favorite stop was Wake Island because it was the only one where she got to see "all that there was to see" (Wake is only four miles long).

After she came home, beating Smith by 25 days, she was also ambivalent about her fame. "I enjoyed a certain amount of it but not the appearances day after day, week after week. Sometimes I didn't know what city I was in." She admitted she didn't push as hard as she might have to exploit her success because she didn't want to continue to take orders and stick to schedules. Yet when Joan Smith won the Harmon trophy for flying around the world (awarded posthumously for her flight around Earhart's equatorial route) and Englishwoman Sheila Scott got "more glory than anybody since Wiley Post for being the first *non-American* woman to do it . . . and had five full-time secretaries answering her mail afterward," Mock was taken aback and not just a little sorry. "I was so naive about things," she said, meaning publicity, endorsements, agents, "so much an amateur then."

At the 94th Aero Squadron restaurant, I vaguely hoped our waiter, a college student

Mock wrote of her stop in Saudi Arabia: "Probably no one had thought to make a law saying a woman couldn't drive an airplane."

COURTESY JERRIE MOCK

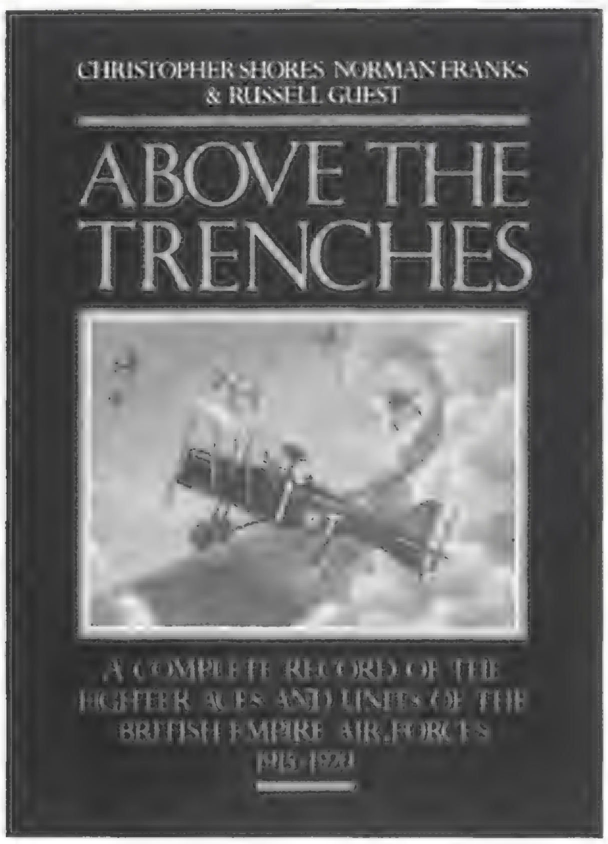
in khaki fatigues, would recognize my once-famous guest, but he didn't. Our table, next to a battered SPAD wing mounted on the wall, gave us a view of taxiing DC-9s and 747s. She told me she had once started and managed briefly a "round-the-world" restaurant at an airport in southern Ohio that served dishes such as "Casablanca Flight 354" (cous-cous) and "Paris Flight 297" (crêpes Monte Christo).

Her feeling of ambivalence never left her. When I asked how she felt about her flight from the perspective of 25 years, she said wistfully, "It turned my whole life around. Although many nice things happened because of it, my life was much nicer before. If I hadn't made the flight, I'd still be flying, maybe working at an airport, being an instructor." Still, she didn't regret the trip. "I believe that I was meant to go," she said. "From the time that I was a child I was destined to do something with an airplane." Besides, she had some powerful memories. In her log she wrote of sandstorms past Tripoli, gold-roofed "pagodas" seen from a distance in Thailand, "light rain over the Persian Gulf and low clouds over the mountains of Serdjah," the Ganges flowing by beneath an empty sky.

During lunch I asked how she felt about giving her airplane to the museum. "Charlie was almost like a child to me," she said. "It was like having a child grow up and go off to school and make a life of its own." Over dessert she signed a photocopy I'd brought of the title page to the last chapter of her book, "Home." Then we left, stopping by the airport's Ohio History of Flight Museum on the way out so I could take some pictures. She posed standing in the open doorway of a Gemini II mockup, her head high, red chiffon scarf flying, eyes squinting against the sun but seeming to see a long way off. It was a victory pose; she'd done this before.

I was thinking to myself, as I was snapping away, that the marketable image of a brave and capable pilot was the very one that seemed to matter least to her. "I knew my limitations and felt that if I used my common sense I'd get back home" was all she said about her skill. What really set her apart was her passion for seeing new places, her undiminished love of travel. So her pose seemed also one of embarkation, facing toward the next distant land. After all these years, my interest may have stirred those feelings somewhat, because she called down from the Gemini, out of the blue, in answer to no question of mine, "If you know anybody who wants a copilot and navigator to fly around the world, let me know, will you? Because that's what I'd like to do."

—*Mariana Gosnell*



Above the Trenches: A Complete Record of the Fighter Aces and Units of the British Empire Air Forces 1915–1920 *by Christopher Shores, Norman Franks, and Russell Guest. Grub Street (London), 1990; distributed in the U.S. by Seven Hills Book Distributors. 397 pp., b&w photos, $55 (hardbound).*

It's common knowledge among World War I historians and buffs that the leading British ace of the war was Mick Mannock, who narrowly edged out Canadian Billy Bishop (who flew for the British) with 73 victories to Bishop's 72. Third place falls to Albert Ball, who destroyed 47 aircraft.

As *Above the Trenches* painstakingly documents, however, that common knowledge is wrong. Mannock had 61 victories—and that's if one counts 20 probables (aircraft driven down out of control) and 10 shared kills as full victories. Of Bishop's 72 victories, 16 were probables and two were shared, but incredibly, most of his claims were not verified by other pilots or by ground observers, and his record is now seriously clouded. Albert Ball, whose father threatened to sue a writer who disputed his son's 47 kills, actually had 44 victories, which included 29 aircraft destroyed, nine forced to land, and six probables.

This is just a sliver of the astounding information contained in *Above the Trenches.* A study of over 800 aces—including Americans—who flew for the British from 1915 to 1920, the book is the result of a 20-year research project by three historians who laboriously combed all extant records of the Royal Flying Corps, Royal Naval Air Service, and Royal Air Force, as well as reliable secondary sources. The study is so complete and well documented that the only controversy it will provoke will be the question of how to assimilate its findings into traditional renderings of the era.

From the first months of the war, each nation's propaganda machine encouraged its citizens to lionize their aces—those pilots having five or more victories. Such heroes provided personal identification to a war in which faceless millions were losing their lives. The British were the exception to the rule. They believed that all pilots contributed equally to the war effort and that creating a few pilot celebrities did disservice to the rest. Eventually, public and media pressure forced them to release "ace" information, but since the British never had an ace system, their record-keeping was not oriented toward ensuring accuracy. Until now British ace rankings were primarily determined by pre-World War II works that relied on secondary sources; because of the considerable difficulties in finding out otherwise, contemporary historians have simply accepted these figures as fact.

This publication changes all that. The book, which contains over 200 photographs, is divided into four sections. The first concisely and intelligently introduces the various problems inherent in the subject. The next provides a background to the 1914–18 air war and the 1918–20 war in Russia—included because some of the same British pilots, squadrons, and aircraft types were involved. The third lists squadron histories and pilots who gained five or more victories while flying with each unit. The final and largest section contains succinct but comprehensive biographies and detailed claim notes for the aces. The authors don't provide final rankings for the aces, however, feeling that the scores often aren't directly comparable or "any useful guide to merit."

Ideally, *Above the Trenches* will motivate historians to publish similar works on American, Austrian, French, German, and Italian aces. A masterpiece of research and revelation, the book affords interesting reading whether for a few minutes or a few hours. *Above the Trenches* and its authors deserve all the kudos they will receive.

—Howard G. Fisher is a director of the San Diego Aero-Space Museum and an editor of Over the Front: The Journal of WWI Aviation Historians.

The Space Station Decision: Incremental Politics and Technological Choice *by Howard E. McCurdy. The Johns Hopkins University Press, 1990. 312 pp., b&w photos, $34.95 (hardbound).*

Most people naturally think of engineering in terms of objects: bridges, dams, airplanes, missiles, and so on. But the most expensive and complex engineering projects, epitomized by those of NASA and the Pentagon, are characterized as much by enormous bureaucracies and labyrinthine decision-making processes as by their dazzling products. And when something goes wrong in one of these big programs, the root cause is as likely to be flaws in management or organization as to be a broken part or an error in calculation.

Yet even after all the spectacular engineering snafus of the past decade or so—Three Mile Island, the space shuttle, the Army's Divad gun, the Hubble Space Telescope—too few journalists recognize bureaucracies as a source of technical disaster. And even fewer historians and policy analysts are able to combine their scholarly expertise with political savvy and

lucid writing to produce studies that are useful outside academic circles. Howard McCurdy's book on NASA's space station project is a laudable example of the type of work that needs to be written. It's a pity that the price of this book will probably keep it out of most voters' hands.

The Space Station Decision tracks the project along its tortuous path from the late 1950s, when a permanent near-Earth habitat first became part of NASA's long-range plans. The bulk of the book examines the period between June 1981, when NASA administrator James Beggs broached the subject before a Senate committee, and January 1984, when President Reagan endorsed it in his State of the Union address. McCurdy recounts that in early 1982, McDonnell Douglas, Boeing, and Rockwell International officials briefed Marshall Space Flight Center and Johnson Space Center employees on the space platform, rather than vice versa. "The centers relied on the contractors, the contractors competed with each other, and the competition rebounded through the agency," he writes. He shows how the $8 billion price tag handed to the White House in 1983 came out of the "mathematics of

budgetary politics" rather than close engineering cost analysis. Yes, the seeds of current disarray were planted early. No, there was no attempt to uproot them until too late.

McCurdy, a professor of public affairs at American University in Washington, D.C., puts the blame on the lack of grand vision for the nation's space program and the resultant necessity for NASA to follow "incremental" strategies. This is hardly an original insight, but no matter. The pearl of his effort is the way he writes about the people and institutions that create the splendiferous objects.

—Wayne Biddle's history of the aerospace weapons industry, Barons of the Sky, *will be published by Simon & Schuster this year.*

Hell-Bent for Leather: The Saga of the A-2 and G-1 Flight Jackets *by Derek Nelson and Dave Parsons. Motorbooks International (1-800-826-6600), 1990. 176 pp., b&w and color photos, $29.95.*

It may strike the uninitiated as remarkable that an item as commonplace as the leather flight jacket could become as enshrined as it has. *Hell-Bent for Leather,* however, doesn't explain the phenomenon so much as become a part of it.

The Russian Right Stuff. *Three episodes of "NOVA" on PBS. To air at 8:00 p.m. EST on February 26, 27, and 28; check local listings.*

NOVA Rips Lid off Soviet Space Program! Headlines would have trumpeted that news had this three-part series come out a few years ago, and even in the midst of the *glasnost* era a lot of the footage is eye-opening. NOVA's cameras were allowed backstage at the Baikonur Cosmodrome and in Star City, and the footage they brought back is truly unique, as is the archival material from Soviet vaults.

Episode one profiles Sergei Korolev, the once-mysterious "chief designer" behind the Soviets' first and most famous space triumphs. Episode two (not available for preview) covers Soviet efforts to beat the U.S. to the moon. The final episode follows two cosmonauts from training through the end of a mission aboard the Mir space station. Space buffs will find it all quite entrancing. *Air & Space/Smithsonian* contributing editor James Oberg acts as on-camera tour guide for the series.

Speaking of the Air Force's re-issuing of its A-2 jacket in 1988 after a 45-year hiatus, the authors observe, "It was like a veteran pilot due back from a long and dangerous combat mission, where the odds were three-to-one against. The pilot was long overdue, but no one at the field ever gave up hope. Then, in the twilight, you heard the engine, and you knew he'd made it once again."

The topic and title may sound familiar to *Air & Space/Smithsonian* readers: the authors first wrote about flight jackets in the April/May 1989 issue and ended up with more material than they could fit into a single article. Along with over 200 photos and interesting historical tidbits, such as the propaganda advantage the Germans scored after capturing an aircrew whose A-2s were painted with "Murder Inc.," Nelson and Parsons have included detailed information for jacket collectors.

Both less exacting and more colorful than Glenn Sweeting's superb *Combat Flying Clothing* (Smithsonian Institution Press, 1984), the book makes no scholarly claims. With an approach similar to last year's *Cowboys of the Sky,* another Motorbooks issue, *Hell-Bent for Leather* links past and present in a happy, sentimental jumble.

—David Walsh is a Washington, D.C.-based journalist and militaria enthusiast.

***Return to the Red Planet** by Eric Burgess. Columbia University Press, 1990. 224 pp., b&w photos and drawings, $34.95 (hardbound).*

***Mars Beckons: The Mysteries, the Challenges, the Expectations of Our Next Great Adventure in Space** by John Noble Wilford. Alfred A. Knopf, 1990. 244 pp., b&w and color photos, $24.95 (hardbound).*

Just what course NASA will chart into the 21st century is the United States space community's most hotly debated issue. Should we focus on Earth orbit activities with the space station Freedom, return to the moon and complete the exploration begun by the Apollo astronauts, or embark on a more ambitious undertaking by exploring Mars, first with unmanned orbiters and later with manned expeditions? For many people, there is only one answer: we must go to Mars.

In *Return to the Red Planet,* Eric Burgess not only explains why and how we should make this journey but updates our understanding of that all-too-enigmatic planet. He also gives a detailed account of the space probes that provided us with the latest information about the planet. In particular, the author takes great pains to explain the science and observations that would have been conducted had the Soviets' 1988 Phobos probes not malfunctioned.

Unfortunately, the approach *Return to the Red Planet* takes to its subject is like that of a textbook. Much of the book is simply a catalog of facts, heavily laden with scientific explanations and terminology. Its text should prove accessible enough for most lay readers, however, and Burgess' discussions of current theories are clear and easily understood, making *Return to the Red Planet* ideal for someone looking for a serious introduction to Mars.

For those in search of more entertaining reading, there's *Mars Beckons* by *New York Times* science correspondent John Noble Wilford. *Mars Beckons* is concerned less with the Red Planet itself than with our fascination with it.

Perhaps the most interesting part of *Mars Beckons* is the description of activities taking place behind the scenes of the Soviet space program and its latest efforts to explore Mars. Capitalizing on *glasnost,* Wilford reveals that the Soviets have their share of political hurdles to overcome, not unlike the obstacles NASA faces.

Both authors conclude their books by arguing that the United States should make Mars a long-term objective of its space program. Unfortunately, they largely fail to make their cases. For Wilford, going to Mars is a matter of destiny: "Humans will go forth to Mars." It is part of our makeup as a species to extend our range, he explains, first across our planet and later into space. Though such reasoning may be

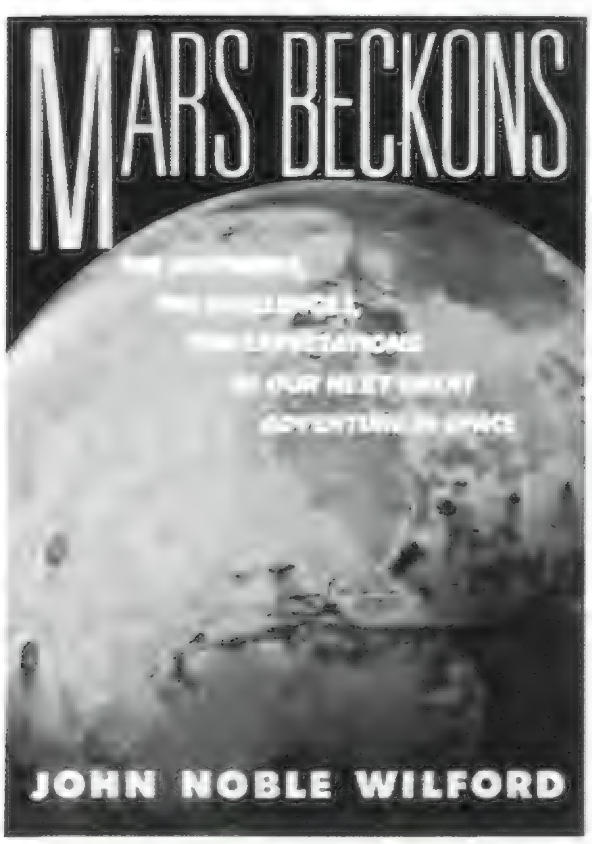
compelling from a philosophical point of view, it offers little as a pragmatic argument that would persuade a nation to spend its limited resources to explore a distant planet.

Burgess takes a more practical tack. An ambitious Mars program, he explains, will boost the economy by producing new technologies, as happened in the wake of the Apollo program. In addition, Mars is the "gateway to the asteroids," a vast storehouse of minerals that can be utilized instead of the resources of our beleaguered Earth. Finally, a Mars program executed in partnership with the Soviet Union and other nations would promote world peace by serving as a model for peaceful relations on Earth.

Though similar arguments have been offered for conducting manned expeditions to the moon and building space colonies, they are too uncertain—too much like wishful thinking—to convince those who must allocate the necessary billions of dollars for such an undertaking. The idea that an international Mars program would promote peace, while tempting, does not ring true: international space programs are the result—not the cause—of better international relations.

Despite their flaws, *Return to the Red Planet* and *Mars Beckons* are well worth reading. If their authors are unable to convince us why we should go to the Red Planet, they succeed in providing a better understanding of that mysterious place and why we are so drawn to it.

—Science writer Robert G. Nichols contributes to Final Frontier, Sky & Telescope, *and other magazines.*



Credits

The Battle of Wyndham. A former art director for *Sesame Street* magazine and records, Robert Pierce has written and illustrated over 20 children's books.

Spaced Out. Ellis Weiner is the author of *Decade of the Year* (E.P. Dutton, 1987). He has written for television, movies, and many publications.

The Rocket Ranch Gang. Ed Regis is the author of *Who Got Einstein's Office?* (Addison-Wesley, 1987). An excerpt from his most recent book, *Great Mambo Chicken and the Transhuman Condition* (Addison-Wesley, 1990), appeared in the October/November 1990 issue of *Air & Space/Smithsonian.*

The Joy of Rivets. After working in the aviation industry for over 45 years, O.H. Billmann now lives and writes in Simi Valley, California.

The Case for Life on Mars. A student intern with the Viking project in his college days, space exploration writer Andrew Chaikin is currently at work on a book about the Apollo lunar astronauts for Viking/Penguin.

Further reading: *The Search for Life on Mars,* Henry S.F. Cooper, Holt, Rinehart & Winston, 1980.

Mars at Last!, Mark Washburn, Putnam, 1977.

To Utopia and Back, Norman Horowitz, W.H. Freeman, 1986.

The Blimp Bowl. John Grossmann is a freelance writer based in Bucks County, Pennsylvania. He has written for *Sports Illustrated,* the *New York Times, Omni,* and the National Wildlife Federation magazines.

Electronic War. Fred Reed is a syndicated military columnist with Universal Press. He has written for *Harper's* and other national magazines.

Soviet Booster. Tom Huntington is the managing editor of *Air & Space/Smithsonian.*

Blue Planet. David Savold is an associate editor at *Air & Space/Smithsonian.*

Luncheon With the Queen. Mariana Gosnell has recently completed a book about small airports, to be published by Knopf. She decided to learn to fly after taking a chartered flight over Kenya that was piloted by a woman.

The Smithsonian Traveler

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Calendar

February 17 & March 17
Open Cockpit Sunday. New England Air Museum, Bradley International Airport, Windsor Locks, CT, (203) 623-3305.

February 20–24
United States Pilots Association winter meeting. Island flying seminar and tour of tropical plantation. Royal Lahaina Resort, Kaanapali Beach, Maui, HI, (913) 469-0003.

February 21–23
Air Law Symposium. Sponsored by the Southern Methodist University School of Law. Loews Anatole Hotel, Dallas, TX, (214) 692-2570.

March 8–10
Students for the Exploration and Development of Space Conference. California Institute of Technology, Pasadena, CA, (818) 351-9858.

Tico Warbird Airshow. Space Center Executive Airport, Titusville, FL, (407) 268-1941.

March 9–April 21
"All Systems Go: America's Space Transportation System for the 1990s." Smithsonian Traveling Exhibition. Kansas City Museum, KS, (816) 483-8300.

March 16–April 28
"Exploring the Planets." Smithsonian Traveling Exhibition. Kansas City Museum, KS, (816) 483-8300.

March 23–April 28
"The View From Space: American Astronaut Photography, 1962–1972." Smithsonian Traveling Exhibition. Federal Reserve Bank, Kansas City, KS, (816) 881-2000.

March 23–May 5
"Visions of Flight: A Retrospective from the NASA Art Collection." Smithsonian Traveling Exhibition. Southern Ohio Museum and Cultural Center, Portsmouth, OH, (614) 354-5629.

March 24–28
Space Expo '91. Washington Convention Center, Washington, DC, (703) 893-0740.

April 5–May 5
"Steichen and His Men: A Photographic Portrait of World War II." Smithsonian Traveling Exhibition. Santa Fe Community College Art Gallery, Gainesville, FL, (904) 395-5310.

"The Satellite Sky" Update/22

These regular updates to "**The Satellite Sky**" chart will enable readers to keep their charts up to date. Additions can be clipped and affixed to the chart at the appropriate altitude.

New launches

90 to 300 MILES

- Cosmos 2102 10-16-90 PL
- Cosmos 2103 11-14-90 TT
- Cosmos 2107 12-4-90 TT
- Cosmos 2108 12-4-90 PL
- Soyuz TM-11 12-2-90 TT

300 to 630 MILES

- Cosmos 2106 11-28-90 PL
- DMSP 12-1-90 VAFB

6,200 to 13,700 MILES

- GPS-10 11-26-90 CAC

21,750 to 22,370 MILES

- Galaxy 6 10-12-90 KOU
- Gorizont 21 11-3-90 TT
- Gorizont 22 11-23-90 TT
- Gstar-4 11-20-90 KOU
- Inmarsat 2 10-30-90 CAC
- SATCOM C-1 11-20-90 KOU
- SBS-6 10-12-90 KOU

Deletions

90 to 300 MILES

Cosmos 2072 down 11-21-90

PRC-27 down 10-13-90

Cosmos 2101 down 11-30-90

Progress M-5 down 11-28-90

630 to 1,250 MILES

Cosmos 2059 down 11-12-90

Launched but not in orbit

90 to 300 MILES

Cosmos 2104 USSR photo recon	11-16-90	down 12-4-90
STS-35 US research	12-2-90	down 12-11-90
STS-38 US research	11-15-90	down 11-20-90

Inoperative but still in orbit

300 to 630 MILES

Cosmos 2016

Forecast

In the Wings . . .

Space Shuttle. It's been 10 years since the first flight, and *Air & Space/Smithsonian* marks the occasion with a poster of the shuttle as it's never been seen before. Plus a look at the political, technological, and economic forces that created the vehicle.

Lifting Bodies. Most people know these test beds from the opening credits of TV's "The Six Million Dollar Man." Test pilots knew them as tricky beasts to fly, and as precursors to the space shuttle.

Race of the Pharaohs. Ultralights soar over the pyramids . . . when they're not grounded for repairs.

STANLEY GEORGE

X-31. The latest in X-planes is a study in maneuverability. If it works as planned, it could rewrite the rules for fighter combat.

Teenysats. When it comes to satellites, bigger is not necessarily better. Sometimes the little guys can get the job done, and they're a lot easier to loft into orbit.

Spacehab. It started as a scheme to launch tourists aboard a big can in the shuttle's bay. It turned into a way to launch science experiments aboard a big can in the shuttle's bay. Now it's won a crucial NASA contract.

I Was a Kamikaze Pilot. A book excerpt reveals that Japan's infamous suicide fliers weren't the crazed fanatics usually portrayed in popular histories.

MAN: This Eagle Talon TSi and Toyota Celica All-Trac both have all-wheel drive. But the Celica costs about 4,000 dollars more.

OFF-CAMERA VOICE: What do those guys at Toyota take us for?

MAN: About 4,000 dollars.

(MUSIC) 

Advantage: Eagle

Chrysler's Newest Division

Eagle Talon TSi with all-wheel drive and 195 horsepower turbocharged, intercooled engine is backed by Chrysler's exclusive 7/70 Protection Plan. This plan protects the engine and powertrain for 7 years or 70,000 miles and against outerbody rust-through for 7 years or 100,000 miles. See limited warranty at dealer. Restrictions apply. Price claim based on comparison of sticker prices. For more information about Eagle Talon, or how to buy or lease one, call 1-800-JEEP-EAGLE.

Buckle up for safety.